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BIONOMICS AND CONTROL OF THE NIGRA SCALE, SAISSETIA NIGRA[1]

RALPH H. SMITH[2]

INTRODUCTION

THE NIGRA SCALE, *Saissetia nigra* (Nietner), has been for many years an important pest of ornamental shrubs and trees in the coastal region of California, and for more than half a century a well-known pest of such plants and of various agricultural crops throughout tropical and semitropical regions of the world. In California there has been some concern lest the nigra scale become a pest of citrus, avocado, and other subtropical fruits. The investigations reported herein were made mainly during 1937 to 1940, when the insect was exceedingly prevalent in the coastal region from Sonoma County on the north to San Diego County on the south.

Homeowners, gardeners, nurserymen, street and park superintendents, and pest-control operators had long needed information which would enable them effectively to control the pest. Control efforts had for many years been generally disappointing because the nigra scale has a remarkably long egg-laying period, extending from about the first of June to the following February, and because spraying had been done in mid or late summer, when only about half the eggs had been laid. In the past few years the control of the scale has been greatly aided by predaceous and parasitic insects. Particularly effective has been the parasite *Metaphycus helvolus* (Compere), introduced into California from South Africa in 1936–37 by the University of California.

This paper gives the results of a comprehensive study of the nigra scale and correlates the findings of a fragmentary literature, comprising a large number of accounts in which references to the insect have been made. The bibliography compiled during the study comprises 215 titles, of which 107 are cited in this paper. About half the total printed matter is found in 10 papers devoted to descriptions of *Saissetia nigra* and its synonyms, and to discussions relating to its taxonomy. These papers are as follows: Signoret (1873), *Lecanium depressum* Targ.; Douglas (1887), *L. depressum* Targ.; Douglas (1891), *L. nigrum* Nietn.; Douglas (1892), *L. begoniae* n. sp.; Maskell (1892), *L. depressum* Targ.; Cockerell (1893), *L. depressum* Targ. and *L. begoniae* Dougl.; Maskell (1894), *L. nigrum* Nietn.; King (1902), *S. nigrella* n. sp.; Newstead (1903), *L. nigrum* Nietn.; and Green (1904), *L.*

[1] Received for publication January 4, 1943.

[2] Professor of Entomology and Entomologist in the Experiment Station.

nigrum Nietn. Only two papers (Essig, 1931; Smith, 1939) are devoted entirely to the nigra scale.

The first published account of the nigra scale is the original brief description in a treatise on coffee pests by Nietner (1861). This treatise was reprinted in a British journal (Nietner, 1862), translated and published in a French journal (Nietner, 1863–64), and issued in a revised edition (Nietner, 1880), each time under a slightly different title. These four printings of the contribution account for the discrepancy in bibliographical citations by different authors.

EARLY HISTORY OF THE NIGRA SCALE IN CALIFORNIA

Plant-quarantine reports of the California State Board of Horticulture indicate that the nigra scale was frequently found on plants shipped into this state before 1900. For many years the insect was known by three specific names: *Lecanium nigrum* Nietner, *Lecanium depressum* Targioni, and *Lecanium begoniae* Douglas. Alexander Craw (1894)[3] briefly discussed the insect under the name depressed scale, *Lecanium depressum,* as follows:

> A dark, flattened, oblong scale, frequently found upon palms and other plants imported from the Sandwich Islands. It resembles a full-grown "soft orange scale" (*L. hesperidum*), but is darker. From the amount of black smut and the dirty appearance of the infested plants, I consider this would be as troublesome a pest as the other *Lecaniums* that have gained a foothold in the State.

Accompanying the statement is a sketch showing a section of a palm leaf and four adult scales.

Two years later Craw (1896) made the following statement under the topic "New black scale, *Lecanium nigrum* Nietner":

> A smooth, oval, shiny, black scale found upon ferns and other plants from the Sandwich Islands. It has been reported to exist in India and Ceylon, where it attacks coffee. Professor Cockerell says it is seldom found on the coffee, though "sometimes present in large numbers upon the croton-oil plant and the ceara rubber, where it produces the usual effect, viz., a heavy fall of leaf and black fungus."

A photograph of a section of a fern leaf bearing several adult scales is shown in this report (Craw, 1896, pl. VI, fig. 6), and the statement is made that all plants found infested with the scale were destroyed.

So far as disclosed by the present study, the first records of the establishment of the nigra scale in California are in the scale-insect collections of E. O. Essig at the University of California and G. F. Ferris at Stanford University. These specimens were examined by the writer in June, 1940. Essig has two vials and Ferris one, all three containing midrib sections of a leaf, to which are attached adult nigra scales and labels stating that the insects were collected by E. M. Ehrhorn on *Monstera deliciosa* in a greenhouse in Golden Gate Park in San Francisco June 11, 1906. Ferris's vial is a part of a collection made by O. E. Bremner, who was connected with the California state quarantine service when Ehrhorn was chief of that service. Bremner[4] says that he well remembers a large specimen of *Monstera deliciosa* which grew in the conservatory in Golden Gate Park, but that he does not specifically

[3] See "Literature Cited" at the end of this paper for complete data on citations, which are referred to in the text by author and date of publication.

[4] Bremner, O. E., in conversation with the author, June, 1940.

remember having taken the nigra scale during the period that he was in the quarantine service. Ehrhorn[5] states that he remembers having collected many Coccidae in the conservatory in Golden Gate Park, but that he does not recall the specific incident of taking the nigra scale in 1906.

Interviews with several persons connected with nursery work prior to 1910 have indicated that the nigra scale was established in the San Francisco Bay region before it was taken in the conservatory in Golden Gate Park. The most reliable information has been supplied by Fred Seulberger, Agricultural Commissioner of Alameda County during the period 1905 to 1930, who has definite recollections of the insect about 1900 when, as a young man, he had the responsibility of hand-picking and otherwise controlling insect pests in his father's greenhouse. He remembers that the scale occurred on Boston ferns and Japanese aralia.

The first published record of the establishment of the nigra scale in California is found in a paper by Ferris (1920), in which the scale is reported as taken on *Euonymus* sp. on the campus of Stanford University. The scale is mentioned in a footnote by Essig (1926), but he says nothing about its distribution or economic importance in California. Steinweden (1930) discussed the taxonomy of certain lecanine scales, including the nigra scale, but he made no mention of its distribution or economic status in California. In a short article, Essig (1931) stated that whereas it formerly was believed the scale would not survive under outdoor conditions in California, the insect had become well established outdoors, owing possibly to a series of rather mild winters. These are the only published accounts of the nigra scale in California prior to 1937, when the present investigation was undertaken.

ESTABLISHMENT AND INCREASE IN VARIOUS COUNTIES IN CALIFORNIA

According to data supplied mainly by the Entomology Division of the State Department of Agriculture and by the county agricultural commissioners, the first recorded identifications of the nigra scale in various counties in California are as follows: Santa Clara County in 1920 (Ferris, 1920); Alameda, Los Angeles, and Marin counties, in 1931; Ventura County, in 1933; Orange, Santa Barbara, Santa Cruz, and San Francisco counties in 1935; San Diego and San Luis Obispo counties in 1937; and Sonoma County in 1939.

There is reason to believe that the scale had been established in these counties long before identifications were first recorded. The Los Angeles County Agricultural Commissioner has a slide mount of the nigra scale, taken in quarantine on plant material from Sonoma County in February, 1926. In view of the widespread existence and abundance of the scale in the coastal region in the years 1936 to 1940, one may assume that it increased markedly in that period or some time before 1936.

Presumably the scale was not widely distributed and was but little known in California in 1913, since it was not mentioned by Essig (1913) in his treatise on injurious and beneficial insects of California. It was presumably relatively scarce in 1920, for Ferris (1920) reported it from only one host and one locality in his study of the scale insects of the Santa Cruz Peninsula.

[5] Ehrhorn, E. M., in letter to the author, November 26, 1939.

In a scale-insect collection made at Stanford University in 1925 and 1926, Myers[6] has a slide mount of the nigra scale taken on *Hedera Helix* (English ivy) in April, 1925. A large specimen of *Pittosporum undulatum*, back of Jordan Hall at Stanford University, is known to have been infested since 1926. The insect commonly occurs on a large variety of shrubs on the Stanford University campus and in all the region from San Francisco to San Jose.

In Los Angeles County, among those who have had occasion to make observations, there is general agreement that the nigra scale increased greatly during the period 1930 to 1940. This is reflected in the number of times the scale has been collected by agricultural inspectors. The numbers of collections for 1933, 1935, and 1938, for example, were 15, 58, and 130, respectively. The Agricultural Commissioner of Los Angeles County states that these figures do not necessarily present a correct indication of the increase in abundance of the scale, however, because more inspection work was done in some years than in others. During 1938 and 1939, the scale was exceedingly abundant on many varieties of ornamental shrubs and trees in the district extending from Pasadena to Santa Monica. The foliage of *Rhus integrifolia* (lemonade berry) was black with sooty mold resulting from the heavy infestation. Tower[7] states that a similarly heavy infestation occurred during the period 1930 to 1932, and that he knows the scale to have existed in the southern coastal region for the past twenty years.

One may readily believe that the nigra scale has become established many times, and in many localities in the state, as the result of having been brought into California repeatedly on plants from tropical and semitropical parts of the world or on greenhouse plants shipped into California from other parts of North America. During the years 1920 to 1922, inclusive, when the names of insects intercepted by plant quarantine inspectors were published, the nigra scale was intercepted on 14 different shipments of plants from Hawaii. From 1927 to 1937 it was intercepted 142 times on plant material received at the ports of San Francisco, Los Angeles, and San Diego. Data given in the Biennial Reports of the California State Board of Horticulture show that, prior to 1900, large quantities of ornamental plants entered the state from foreign countries and particularly from Hawaii, where, as indicated by Craw (1894), the insect appears to have been rather common as early as 1894. During most of the first two instars, the insect is less than 1 mm in length, and is semitransparent. In this stage it may easily escape detection. Therefore, considering the quarantine-interception record, one may suppose that prior to the instituting of rigid regulation and inspection of foreign plant shipments, about 1912 or 1915, the nigra scale may have entered the state many times. Since the scale reproduces parthenogenetically, one immature insect would be capable of giving rise to an infestation under favorable conditions of environment.

GEOGRAPHICAL DISTRIBUTION

Distribution and Prevalence in California.—In surveys made during 1938, 1939, and the last half of 1940, in the course of the present study, the nigra scale was found throughout the coastal region of California from Sonoma

[6] Myers, Emery, Agricultural Inspector, Office of Agricultural Commissioner, Los Angeles County.

[7] Tower, C. R., State Nursery Inspector, in letter to the author, October 2, 1939.

County to San Diego County. Except in Los Angeles County, where intensive observations have been made, the surveys were limited to the inspection of a small number of species of host plants, including *Pittosporum undulatum, Pittosporum eugenoides, Nerium Oleander* (oleander), *Ilex* spp., *Photinia (Heteromeles) arbutifolia* (California holly, toyon), *Hedera* spp., and *Eugenia* spp. The surveys were not particularly thorough, involving for the most part the inspection of occasional host plants sighted while the writer was driving along highways and through cities and villages.

The scale varied greatly in prevalence and abundance in different localities. It was found most commonly and in greatest numbers in the southern coastal region, from Santa Barbara to San Diego. The most heavily infested area was in Santa Monica and the western portion of Los Angeles. In that area, during 1938 and 1939, many varieties of shrubs and trees growing in dooryards, parks, on estates and along streets, were black with scale and sooty mold. *Pittosporum undulatum,* grown extensively as a street tree in the southern counties, was commonly very unsightly during the fall, winter, and spring. The sidewalks and parked cars under the trees were covered with honeydew. Lemonade berry, *Rhus integrifolia,* which grows in abundance in the southern foothills of the Santa Monica Mountains, was so heavily infested that the shrubs were predominantly black rather than green, as a result of the heavy covering of sooty mold. Large numbers of heavily infested plants were common in some sections of Santa Barbara, Pasadena, Glendale, and San Diego, and intermediate places.

In the central coastal region, from Sonoma County to Monterey County, the scale was found at all localities where inspections were made, although heavy infestations were not so common as in the southern coastal region. Several heavily infested specimens of *Ilex Aquifolium* (English holly) were found in different parts of Santa Rosa, but most specimens of this and other preferred hosts examined there were free of the scale. No infestations were found between Santa Rosa and Ukiah. The scale was much more prevalent at San Rafael than at Santa Rosa. Peryam[8] states that in 1939 the scale was very prevalent on ornamental plants throughout the southern part of Marin County. It was not found to be as prevalent or as abundant on the east side of the San Francisco Bay region as on the west side. Many specimens of preferred host plants were examined in various parts of Richmond, Berkeley, Oakland, Alameda, and other cities south to San Jose, but only a small percentage were infested. The scale was also very scarce in San Francisco, but more recently Walther[9] has reported that the scale is rather common in the warmer parts of the city. It was common and often abundant on preferred hosts from San Mateo south to San Jose, and common at Los Gatos, Santa Cruz, Watsonville, and Salinas. Southeast of Watsonville a thicket of *Pittosporum eugenoides* was found to be very heavily infested. In all the region from Salinas to Santa Rosa, plants of *Ilex* spp. were more commonly infested than other preferred host plants. The scale was not found any place on Highway 101 between Salinas and San Luis Obispo. A nurseryman at Paso Robles

[8] Peryam, Thos. W., Agricultural Commissioner of Marin County, California, in letter to the author, September 6, 1939.

[9] Walther, E., Assistant Superintendent, Golden Gate Park, in letter to the author, November 13, 1939.

said he had repeatedly received infested nursery stock, but his experience indicated that the scale would not survive there.

A search for the nigra scale was also made from San Rafael east to Sacramento, thence south to Stockton and west to Martinez. The only infestation found was in a lath-house at Napa; a few specimens of *Ilex* sp. had been rather badly infested, but the infestation had become greatly reduced as a result of spraying. The Entomology Division of the California State Department of

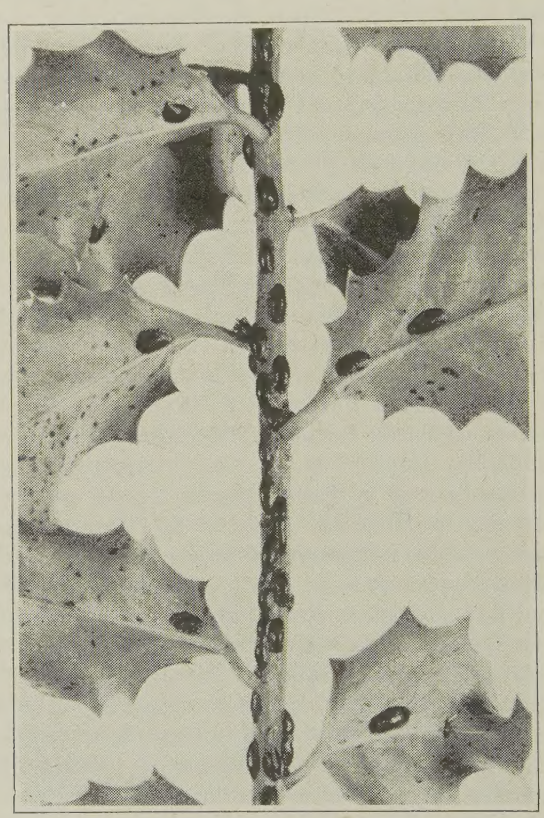

Fig. 1.—Infestation of nigra scale on English holly, in a nursery lath-house at Redlands, California. Photographed November 3, 1941.

Agriculture has a record of the scale taken on a specimen of *Nerium Oleander* in Stockton in 1938. The infested plant came from a nursery in Stockton but may have been part of stock that originated in the coastal region. Keifer[10] points out that the climate of the Delta region, as affected by the confluence of the Sacramento and San Joaquin rivers and by Suisun Bay, may be sufficiently like the coastal climate to enable the nigra scale to exist.

Two additional records of interest were obtained in October, 1941. Steinweden[11] reported finding the nigra scale on several large *Ilex Aquifolium*

[10] Keifer, H. H., in letter to the author, November 21, 1939.
[11] Steinweden, J. B., in letter to the author, October 29, 1941.

plants growing in tubs and in 5-gallon cans in a nursery at Lodi. The infestation had apparently existed for several years. Tower[12] reported the finding of an infestation of nigra scale on *I. Aquifolium* and on *Hedera Helix* in a nursery lath-house at Redlands. The plants had been grown from seed by the local nurseryman and were four or five years old. The infestation evidently had existed for two or three years. The scale appeared to have thrived splendidly, as is indicated in figure 1. A large number of robust adult scales may be seen on the bark of the main stem and along the midribs of the leaves, and many young scales on the leaf surface. Tower stated that in preceding years he had found a similar infestation of nigra scale in a lath-house in San Bernardino.

Occurrence in the United States outside California.—The nigra scale has been reported from the District of Columbia and eight states besides California: New York, Pennsylvania, Ohio, Oklahoma, Texas, Louisiana, Alabama, and Florida. Since there is a dearth of information on insect pests of greenhouse plants in most states, the nigra scale may be more prevalent than is indicated by the few published records. Such records merely mention the identification of the scale.

In October, 1940, the writer found the nigra scale on *Begonia* sp. and *Nerium Oleander* in a greenhouse at Topeka, Kansas, and on *Nerium Oleander* in a private home at Lone Elm, Kansas. The latter plant had remained outdoors all summer, and had become rather heavily infested and covered with sooty mold. When this plant was first examined, on October 26, 1940, insects in all stages of development were present. The finding of the scale indoors in Kansas in the two instances mentioned should probably be regarded as fortuitous and does not necessarily indicate that the scale is prevalent there. Lawson (1917), in his treatise on the Coccidae of Kansas, does not mention the nigra scale.

So far as has been determined in the present study, Florida is the only state except California where the nigra scale is known to exist outdoors. The first published account of its occurrence in Florida is by Merrill and Chaffin (1923). It was reported from several widely separated localities, including St. Petersburg, Bradenton, and Ellenton on the west coast, Lake Wales in the interior region, Orlando and Sanford in the east central region, and a number of places on the east coast from Cocoa to Miami. This wide distribution indicates that the insect had been in Florida long before 1923. As it was reported from the West Indies by Cockerell in 1893 and since 1904 has been known to be a pest of many plants in the West Indies, one may assume that it was introduced into Florida at an early date. Berger[13] reports as follows: "Our records indicate that hibiscus seems to be its favorite host in Florida and that infestation is at times very severe. Turk's Cap (*Malvaviscus arboreus*) is probably next after hibiscus as a favorite host."

The nigra scale will probably thrive outdoors, to a limited extent at least, all along the Gulf of Mexico. The reports of its occurrence in Alabama, Louisiana, and Texas, referred to above, are from the files of the Insect Pest Survey,

[12] Tower, C. R., in conversation with the author during an inspection of the infestation, October 24, 1941.

[13] Berger, E. W., Entomologist of the Florida State Plant Board, in letter to the author, August 2, 1940.

and no information is given as to whether the scale was found in greenhouses or outdoors.

World Distribution outside the United States.—Records of distribution given in the extensive literature on the nigra scale indicate that the insect occurs very generally throughout tropical and semitropical regions of the world, and that in temperate regions it is widely distributed in greenhouses. Its native habitat may be regarded as southeastern Asia or islands of that region. The scale may have been carried to many parts of the world by ocean commerce in the early part of the nineteenth century. Nietner (1861, 1880), as previously noted, reported it on coffee trees in Ceylon. Targioni (1867) and Signoret (1873) reported it on various greenhouse plants in Italy and France, respectively.

The small number of records on distribution prior to 1880 does not necessarily indicate that the scale had a limited distribution, but rather that the study of economic entomology, and scale insects in particular, had received but meager attention. Between 1880 and 1900, the nigra scale was reported from England, Germany, New Zealand, Australia, India, Hawaiian Islands, British Guiana, Brazil, and a few of the islands of the West Indies, including Trinidad, Jamaica, Puerto Rico, Barbados, and Granada. During that period it also was recorded from Mauritius, off the east coast of Africa. In 1902 King described it as *Saissetia nigrella* from Natal, South Africa, and in later years it was reported from many places throughout the African continent. Reported on the mainland of Japan in 1909 by Kuwana, it subsequently became widely distributed in greenhouses in the temperate parts and outdoors in the warmer parts of Japan. Clausen (1931) lists it from China. It is also reported from Formosa, Malay, Indo-China, Siam, and from the Philippine Islands, the East Indies, and the South Sea Islands.

There are but few published records of the nigra scale in Australia. The first record was by Maskell in 1892. The scale was not mentioned by French (1891–1911) in his treatise on Australian insects but was recorded by Green in 1916. Froggatt in 1921 stated that it had been found on vines and *Hakea* sp. (needle bush) in New South Wales. Only three additional records of the scale in Australia, all between 1892 and 1934, are found. But correspondents with entomologists in Australia and observations made in 1931 by S. E. Flanders, in connection with his search for scale parasites, reveal that the nigra scale occurs on many hosts and is not uncommon along the east and southeast coast of that continent. It appears to be of minor importance as a pest.

Before 1900 the nigra scale was recorded from Brazil and British Guiana in South America. So far as determined in the present study, the only other localities in South America where the scale has been recorded since 1900, are Peru, where it was reported on cotton by Townsend in 1926, and Bolivia, where it was reported on coffee by Bardales in 1929. It has been recorded from Panama, Guatemala, and Salvador; and Ferris (1921) reported it from La Paz, Baja California. There is reason to believe that it is probably widely distributed in South America and in Mexico, wherever suitable conditions of environment prevail.

Some idea of the world distribution of the nigra scale by countries may be obtained from the following tabulations, which include the years in which

reports of the scale were published. This summary is not complete because not all the extensive literature on the subject was available for review in the present study.

AFRICA

Belgian Congo, 1934
Dahomey, 1914
Dutch Africa, 1914
Egypt, 1923, 1924
Kenya (formerly British East Africa), 1915, 1916, 1924, 1929
Mozambique, 1931
Reunion, 1914
Rhodesia, 1933
St. Thomas, 1917, 1918
Seychelles, 1913, 1914, 1925, 1932
Tanganyika Territory (formerly German East Africa), 1913, 1929
Uganda, 1913
Union of South Africa, 1902 (Natal), 1917, 1931 (Transvaal), 1936
Zanzibar, 1913

ASIA AND EAST INDIES

Ceylon, 1840, 1861, 1896, 1904, 1914, 1915, 1916, 1918, 1920, 1921, 1923, 1927, 1932, 1933, 1934
East Indies, 1928
Formosa (Taiwan), 1916, 1937
India, 1916, 1917, 1919, 1920 (North Bihar), 1931, 1932, 1933, 1934, 1936
Indo-China, 1921
Japan, 1935, 1937, 1939
Java, 1916, 1927
Labuan, 1924
Malay, 1922, 1925, 1929, 1933, 1937
Philippine Islands, 1903, 1905, 1915, 1916, 1936, 1937
Siam (Thaï), 1921
Sumatra, 1918, 1927

PACIFIC ISLANDS

Fiji Islands, 1915, 1922, 1924
Guam, 1934
Hawaii, 1894, 1896, 1913, 1918, 1919, 1920, 1921, 1922, 1924, 1925, 1926, 1929, 1932, 1934, 1935
Marquesas Islands, 1935
Samoa, 1916, 1927

AUSTRALIA

Australia, 1916, 1921, 1934
Queensland, 1917, 1919, 1928

EUROPE

England, 1887, 1895, 1917
Germany, 1876
Italy, 1867, 1932

CENTRAL AMERICA

Canal Zone, 1922, 1925
El Salvador, 1931
Guatemala, 1929, 1935
Panama, 1920

NORTH AMERICA

California, 1926, 1930, 1931, 1939
District of Columbia, 1916
Florida, 1923
Mexico, 1921 (Baja California), 1935
New York, 1926, 1930, 1933
Ohio, 1923
Pennsylvania, 1932
United States, 1916, 1923

SOUTH AMERICA

Bolivia, 1929
Brazil, 1897
British Guiana, 1913, 1914, 1915, 1917
Ecuador, 1926
Peru, 1926

WEST INDIES

Antigua, 1917, 1918, 1919
Bermuda, 1928
Cuba, 1933
Jamaica, 1896, 1916, 1921, 1925
Lesser Antilles, 1901, 1921 (Barbados)
Puerto Rico, 1931
St. Vincent, 1913, 1914, 1916, 1922, 1924, 1926
Tobago, 1919
Trinidad, 1916, 1919
Virgin Islands, 1923
West Indies, 1904, 1913, 1915, 1916, 1917, 1921

COMMON NAMES OF THE NIGRA SCALE

During the one hundred years that *Saissetia nigra* has been known to agriculturists and entomologists, seventeen common names in the English language have been given to the insect. In the early years of coffee growing in Ceylon, it was known as the "black-bug," a name which appears to have been used from about 1847 to 1900 (Nietner, 1880; Green, 1896). With the spread of the pest to other parts of the world, other common names appeared in the

literature of agriculture and entomology. The name "black scale" has been used more extensively than any other common name. In the United States, however, the name "black scale" has for sixty years been applied to another species, *Saissetia oleae* (Bernard), which is an important pest of citrus, olives, and many other plants in California. The application of the name "black scale" to two species of insects has been the cause of errors in entomological literature. For example, entomologists of foreign countries have occasionally erroneously stated that *Saissetia nigra* is an important pest of citrus trees in California.

In 1912 the name "flat black scale" (Ehrhorn, Fullaway, and Swezey, 1912) was proposed to the Hawaiian Entomological Society, but this name was not subsequently used in entomological writings in the Proceedings of the Society. The name "hibiscus shield scale" (Cockerell, 1894; Maxwell-Lefroy, 1901) has been used rather generally and is based on the fact that, in many regions outside of California, hibiscus is a favorite host plant. "Begonia shield scale" (Cockerell, 1894) and "black-shield scale" (Wilson, 1923) have also been used. The term "shield scale" was used in older writings to designate the lecanine scales as a group. Cockerell (1896) used the term "black scale of India" to distinguish *Saissetia nigra* from similar lecanine scale insects in the West Indies. Ayyar (1936) in India used the name "common black scale," presumably to distinguish *Saissetia nigra* from other less prevalent species of black scales. The names "soft black scale," "black scale," "flat black scale," and "hibiscus scale" have been used in Hawaii, where the scale has been a well-known pest for a half century.

The first published account of *Saissetia nigra* in California was under the name of "the depressed scale," *Lecanium depressum* Targioni (Craw, 1894). In 1896 Craw identified it by the specific name *Lecanium nigrum* Nietner and referred to it as the "new black scale." With the spread and increase of the pest throughout the coastal region in the last fifteen years, there arose the need for a common name that would distinguish it from *Saissetia oleae,* long known as the "black scale" in California and elsewhere on the mainland of the United States. The names "true black scale," "tropical black scale," "Florida black scale," "flat black scale," "negro scale," and "nigra scale" have had usage among gardeners, nurserymen, and individuals concerned with insect control in California. Only three of these names have been used in writings: "negro scale," by Essig in 1931; "Florida black scale," by Woodhams in 1939; and "nigra scale," by Smith in 1939. When the present investigation of the scale was undertaken in 1937, the common name "negro scale" was chosen. After a review of the literature, however, and with further knowledge of the diversity of nomenclature as indicated above, the name "nigra scale" was selected as an appropriate designation by which the insect might become universally known. This name has doubtless been used to some extent by students of scale insects, in conversation but apparently not in publications, to designate the species *nigra* as distinguished from *oleae* or other species of the genus *Saissetia.*

SYNONYMY AND IDENTIFICATION

As previously noted, the nigra scale was described and given the name *Lecanium nigrum* by J. Nietner in 1861. Since 1861 the scale has been erroneously described as a new species by four different authorities on scale insects. Six specific names—*nigrum, depressum, simulans, begoniae, nigrella,* and *pseudonigrum*—are recorded in the literature. Some authorities have placed the names *depressum, simulans,* and *begoniae* in the category of varieties. The scale has been assigned to three different genera, *Lecanium, Saissetia,* and *Coccus,* by various writers. A list of the names, and the authorities who first used the names, follows:

Lecanium nigrum Nietner (1861)
Lecanium depressum Targioni (1867)
Lecanium simulans Douglas (1887)
Lecanium depressum Signoret (Douglas, 1887)
Lecanium begoniae Douglas (1892)
Lecanium (*Saissetia*) *nigrum* Nietner (Cockerell and Parrott, 1899)
Lecanium (*Saissetia*) *nigrum* var. *depressa* (Targioni) (Cockerell and Parrott, 1899)
Lecanium (*Saissetia*) *nigrum* var. *begoniae* (Douglas) (Cockerell and Parrott, 1899)
Saissetia nigra (Nietner) (King, 1902)
Saissetia depressa (Targioni) (King, 1902)
Saissetia begoniae (Douglas) (King, 1902)
Saissetia nigrella King (1902)
Coccus nigrum (Nietner) (Kirkaldy, 1902)
Saissetia depressa var. *simulans* (Douglas) (Fernald, 1903)
Lecanium pseudonigrum Kuwana (1909)

Targioni (1867) gave the name *Lecanium depressum* to a scale that he found on an exotic species of *Ficus,* and other plants having leathery leaves, in the hothouse of the Royal Museum at Florence, Italy. His description consisted of a footnote of two sentences and was very inadequate. Signoret (1873) gave a more complete description of *L. depressum,* based upon specimens found on *Ficus marticinensis* at Florence, Italy, and on *Ficus elastica* in a hothouse in Paris. Targioni and Signoret may not have known about *Lecanium nigrum,* for they made no mention of it in their treatises on the Coccidae.

In a redescription of *Lecanium depressum,* based upon specimens taken on *Ficus elastica* and *Camellia* in England, Douglas (1887) credited the name *depressum* to Signoret. His reason for doing this is indicated in the following quotation: "Signoret attributes the name *depressum* to Targioni-Tozzetto (Studii sulle Cocciniglie, p. 29, and Catalog, p. 37), and doubtless correctly, but as in neither place is the species described, the reference cannot be cited: Signoret really first described the species." In this article, Douglas inadvertently introduced into the literature the name *Lecanium simulans:*

> At first I was inclined to describe my examples as a new species, under the name of *L. simulans,* but as the other characters given are present, and in view also of the variation admitted by Signoret, I have concluded that there are scarcely sufficient grounds to establish a distinct species. Yet it may be that if one had all the forms before him contemporaneously, two or three good species might be determined.

The name *simulans* was apparently mentioned but twice in literature subsequent to the publication of the paper by Douglas. Fernald (1903) lists *simulans* as a variety of *Saissetia depressa.* Leonardi (1920) lists *Lecanium*

depressum var. *simulans* as a synonym of *Coccus hesperidum* Linn. *Lecanium begoniae* was described by Douglas (1892) from specimens taken on leaves of begonia from Georgetown, British Guiana.

Maskell (1894) made a critical study of *Lecanium nigrum*, *L. depressum*, and *L. begoniae*, and arrived at the following conclusion:

> Taking therefore these important features,—the epidermis, the antennae, and the foot,—it seems fairly clear that there is no real difference between the three insects named, at least as far as concerns the adult female. The females of the second instar appear to be equally similar.... Possibly *L. begoniae* might be looked on as a variety on account of its antenna, and *L. depressum* on account of unequal digitules; but these are doubtful differences, and the three must be taken as really one species.

Green (1897) concurred in Maskell's conclusion, as shown by the following quotation from his paper: "I agree with Mr. Maskell in considering that *L. depressum* Targ.-Tozz. and *L. begoniae* Dougl. are identical with or at the most, varieties of Nietner's species." Later Green (1904) gave a very complete description of *L. nigrum*, and listed *L. depressum* and *L. begoniae* as its synonyms, as had Newstead (1903). Maskell, Green, and Newstead were eminent authorities on the Coccidae and were in favored positions to study specimens theretofore determined, from type localities and host plants. Their agreement would appear to establish the synonymy conclusively. The great majority of later writers have accepted that synonymy. Among those who have not accepted it are Froggatt (1915, 1921), Dash (1916), Costa Lima (1922), and Myers (1922), all of whom, without explanation, used the name *Lecanium depressum* Targ. or *Saissetia depressa* (Targ.).

King (1902) described *Saissetia nigrella* from specimens taken at Natal, South Africa, on *Ficus* sp. Brain and Kelly (1917) regarded *S. nigrella* as a synonym of *S. nigra*. As indicated in the section on taxonomy in the present paper, the writer is disposed to agree with Brain and Kelly, and believes that *Lecanium pseudonigrum* Kuwana should also be regarded as a synonym. Kuwana's description is so brief as to be of little use but, such as it is, is applicable to *S. nigra*.

Cockerell and Parrott (1899) placed *Lecanium nigrum* in the category designated by them as the "Group Saissetia." If they intended to place the species in the genus *Saissetia*, they failed to make their intention clear. King (1902), without explanation, first used the name *Saissetia nigra* (Nietn.). The majority of writers since 1902 have used the name *Saissetia nigra* (Nietn.); but many, including Green (1904, 1915), have adhered to the name *Lecanium nigrum* Nietner. Kirkaldy (1902) is the only writer who has placed *nigrum* in the genus *Coccus*.

TAXONOMIC DESCRIPTION OF THE NIGRA SCALE

Many descriptions of *Saissetia nigra* (Nietn.) and its synonyms appeared in publications during the period from 1861 to 1904. The more important were contributed by Nietner (1861, republished in 1862, 1863, and 1880), Douglas (1887, 1891, 1892), Maskell (1894), King (1902), Newstead (1903), and Green (1904). The only descriptions that can be regarded as in any sense critical or adequate are by Maskell (1894), Newstead (1903), and Green (1904). The only description of any value appearing after 1904 is in a paper by Stein-

weden published in 1930. The descriptions deal in considerable part with such characters as color, shape, size, configuration of the back, and segmentation of antennae, and most of the descriptions fail to note the wide variability in these characters. This fact is well exemplified by King (1902) in his characterizations of *S. nigrella, S. nigra,* and *S. depressum,* all later reduced to the single species, *S. nigra.*

Description of Egg.—When first laid, the egg is translucent colorless or whitish, or sometimes faintly pinkish. As incubation advances, the translucent-colorless eggs become pale rose, pale orange, or pale salmon. For a period before hatching, the eyes of the embryo appear distinctly as minute brown specks; and when viewed with light passing through the egg, the segmentation of the body can be seen. The egg is thinly covered by fine particles of white substance, apparently deposited on the egg by wax pores as the egg is laid. The surface of the egg glistens except where heavily covered with wax particles. The size of the egg varies considerably, being influenced in part by the size of the parent female. The length

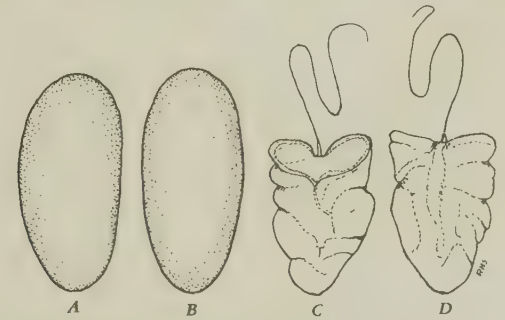

Fig. 2.—Egg and eggshells of nigra scale: *A*, lateral view and *B*, dorsal view of egg; *C*, dorsal view and *D*, ventral view of eggshell.

ranges from 0.29 to 0.37 mm, and the width from 0.14 to 0.19 mm. In dorsal aspect (fig. 2, *B*) the egg is elongate-oval, the anterior portion being more broadly rounded than the posterior portion. In lateral aspect (fig. 2, *A*) the dorsal side is more curved than the ventral, and the anterior portion is thicker than the posterior.

Green (Cotes, 1889; Green, 1904) and Douglas (1891) mention the eggs of *Saissetia nigra.* Douglas states that the eggs are pink, a term which may be regarded as corresponding with the terms "rose" and "orange," as used in the description given above. Green, in an early description (Cotes, 1889), states that the eggs are pale red; but in 1904, in a comprehensive description of the scale, he states that the eggs are purplish. In the present study, occasional batches of eggs were purplish, but these were believed to be dead. Sometimes entire batches are killed by mites and undetermined agencies. Dead eggs are found more commonly in winter and invariably are dark, often purplish.

Description of Empty Eggshell.—The eggshells occur in a compact white mass in the cavity formed by the shrinking of the body of the parent female. The empty eggshell of *Saissetia nigra,* distinctly different from that of other soft scales commonly infesting ornamental plants in California, is triangular in outline and collapsed dorsoventrally. It has numerous creases or folds, and a fine thread is attached to the median anterior ventral edge. The thread is about the same length as the unhatched egg. In dorsal aspect (fig. 2, *C*), the empty shell appears somewhat like the bag of an insect-collecting net, with the opening on the top side drawn backward toward the end of the bag. The ventral aspect is shown in figure 2, *D.*

Description of Crawler.—The live crawler is pale amber, the density of color varying somewhat with the color of the object on which the crawler rests when it is observed. Green (1904) states that the crawler is dull red. The body is oval in outline (fig. 3), and very thin.

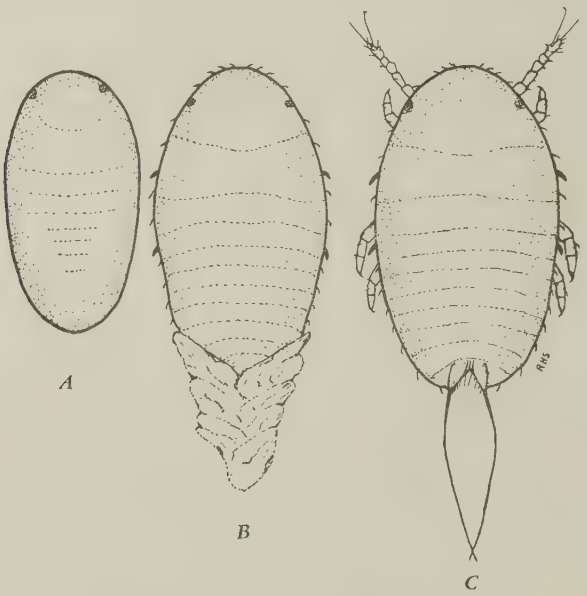

Fig. 3.—Early stages in the development of the nigra scale: *A*, embryo, as seen within the eggshell; *B*, larva emerging from eggshell; *C*, crawler, showing position of antennae during forward movement.

Fig. 4.—First-instar, newly settled stage of the nigra scale.

Specimens ranged from 0.33 to 0.42 mm in length and from 0.17 to 0.24 mm in width. Two anal filaments, about half as long as the body, arise from the tips of the elongate anal plates, and drag as the crawler walks. The antennae are 6-segmented and, when the crawler walks, are held diagonally in front of the head, at an angle of about 45° with the median line of the body. The distal segment bears 2 long bristles and several short, fine bristles. One of the long bristles is strong and straight, and is borne on the tip of the segment; the other is more slender, curved toward the end, and is borne on the side of the segment.

Thirty-two marginal setae and 4 strong stigmatic setae, each set between 2 very short tuberclelike setae, are plainly visible when live or slide-mounted specimens are viewed under a microscope. The position of the marginal setae in relation to the stigmatic processes and the eyes is shown in figure 4, which illustrates the newly settled insect. The abdomen is 8-segmented, but the segmentation is indistinct, both with living specimens and with slide-mounted, stained specimens. Each anal plate bears 1 subapical seta and 3 short apical setae in addition to the long anal filament. There are 2 fringe setae and 6 anal-ring setae.

Description of First-Instar, Settled Stage.—The color of the scale in the newly settled stage is reddish, sometimes changing to translucent greenish for a period before the first ecdysis. The eyes are sharply black. The two caudal filaments of the crawler stage become somewhat atrophied or distorted, and the anal plates and anal cleft unite, as shown in figure 4. The body becomes oblong-oval in outline. The marginal setae and stigmatic setae are plainly visible. Immediately after settling, the

body is about 0.4 mm long and 0.2 mm wide. At the time of the first ecdysis the length is about 0.7 mm and the width about 0.4 mm.

Description of Second-Instar Larva.—Numerous characters readily distinguish the second instar from the settled stage of the first instar. When the insect occurs on a protected part of a plant, the shed first-instar skin may remain attached to the second instar, as shown in figure 5, *A*, for a period of days or weeks. The shed skin is about 0.45 mm long, and the antennae are peculiarly situated about midway along the skin rather than at the end.

The second-instar larva, when viewed upon a leaf, appears typically translucent greenish lemon, the green color of the leaf showing through the body of the insect. When the insect develops on the top side of a leaf and is more or less exposed to sunlight, a pattern, composed of brown or rusty-red imperfect bands of varying regularity and density, may occur on the dorsum (fig. 5, *B*). This pattern also occurs on many third-instar scales. The characteristics

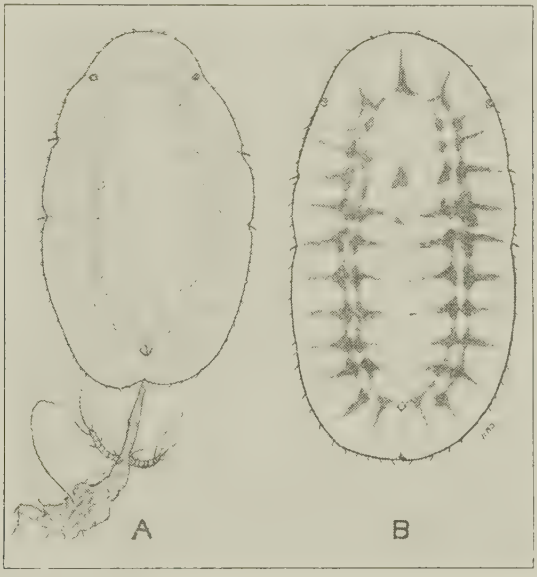

Fig. 5.—Second-instar nigra scale: *A*, scale soon after first ecdysis, showing shed first-instar skin attached to the end of the body; *B*, pattern on the dorsum of many second-instar and immature third-instar scales.

of the pattern are indicated in figure 5, *B*. Green (1904) states that the pattern is "formed by seven longitudinal stripes crossed by eleven or twelve transverse bands, the points of intersection dilated." The present writer finds that there are 4 longitudinal bands and that the cross bands are indicated by approximately 23 tapering processes extending nearly to the margin of the body. Most of the scales occurring on the lower side of the leaves and on well-shaded parts of the plants do not exhibit the markings.

The body is about 0.8 mm long and 0.4 mm wide immediately after the first ecdysis, about 1.7 mm long and 0.8 mm wide immediately before the second ecdysis. These measurements pertain to scales that develop on broad-leaved plants such as *Ilex*, *Pittosporum*, and *Fatsia* (*Aralia*). Scales that develop on narrow leaved plants, such as *Asparagus plumosus* (asparagus fern), may be three times longer than wide.

The dorsum is covered by a thin layer of transparent wax, which can be broken and lifted in sections with the aid of a fine pointed dissecting needle. When specimens are cleared in a warm 10 per cent solution of sodium hydroxide and observed in the solution over a black background, wax areas can be seen around the margin and over the back of the body. The areas correspond in number and arrangement to similar areas on the adult scale (see fig. 13).

Fine glassy filaments are produced submarginally and project upward and outward from the body. Some of the filaments may be twisted, but they are usually perfectly straight and often have a bluish cast. They are brittle, and even in well-sheltered situations, many scales must be examined in order to find one with the filaments intact. In such situations the surfaces of infested leaves may bear tangled masses of the filaments, visible only under a magnification of 10 or 15 diameters. The number of filaments ranges from 5 to 14 for each scale; the usual number is 5 to 8. They are not symmetrically distributed: one side of the body may have 4 or 5 filaments, and the opposite side may have but 1. Examination of the frequency distribution of the filaments on a large number of living specimens showed a maximum of 14 filaments arranged symmetrically, as illustrated in figure 6. Green (1904) states that the filaments arise from points corresponding to the extremities of the transverse colored bands. The present writer has

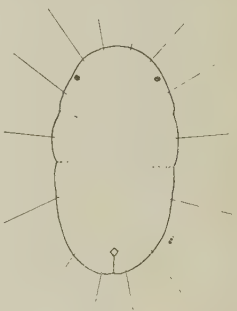

Fig. 6. — Outline of larva of nigra scale, showing maximum number of marginal, glassy filaments and their distribution.

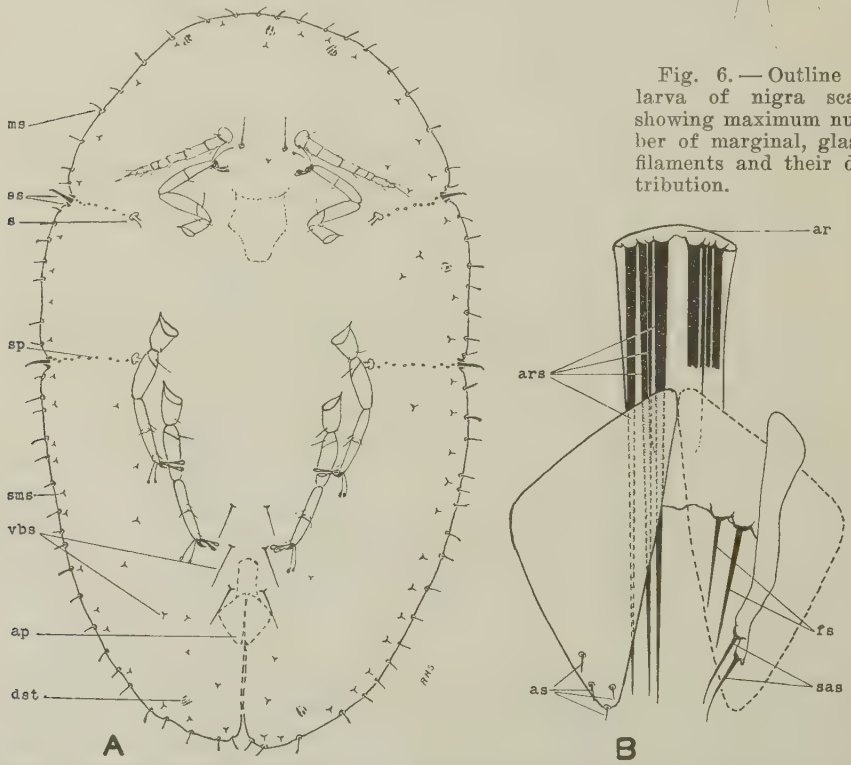

Fig. 7.—Second-instar nigra scale: *A*, ventral view showing various ventral structures, marginal setae, and dorsal submarginal tubercles: *ms*, marginal seta; *ss*, stigmatic setae; *s*, spiracle; *sp*, stigmatic pores; *sms*, submarginal seta; *vbs*, ventral body setae; *ap*, anal plates; *dst*, dorsal submarginal tubercle as seen through the body; *B*, anal plates, anal ring, and attendant setae: *ar*, anal ring; *ars*, anal-ring setae; *as*, apical setae; *sas*, subapical setae; *fs*, fringe setae.

not been able to confirm this statement. In fact, the filaments arise from conelike structures (figs. 7 *A*, and 9, *A*, *dst*), as can be seen by examining specimens under a compound microscope. The specimen shown in figure 7, *A*, has six such structures (fig. 7, *dst*).

The eyes are black. The internal organs, and objects resembling fat bodies, can readily be seen with transmitted light under a microscope. The antennae are 7-segmented. The legs are substantially like those of the third-instar scale described on a following page.

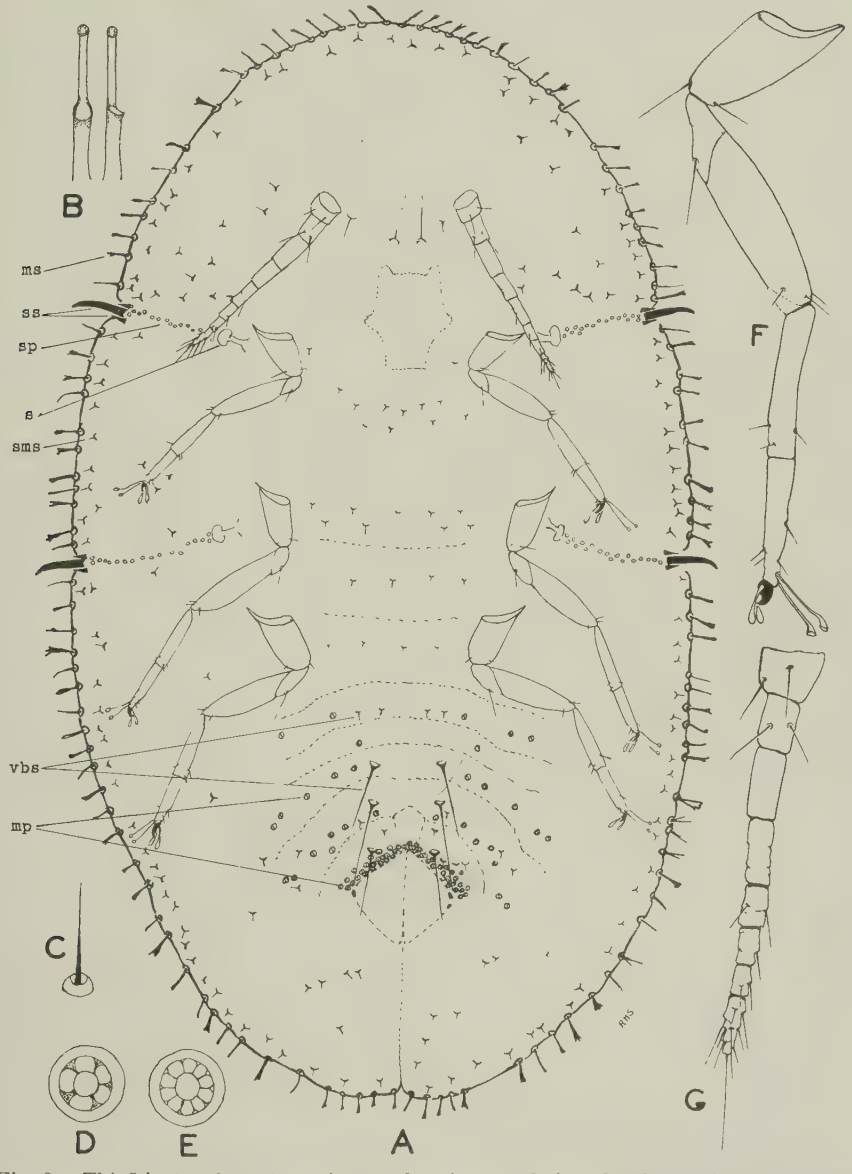

Fig. 8.—Third-instar, immature nigra scale: *A*, ventral view showing various ventral and marginal structures: *ms*, marginal seta; *ss*, stigmatic setae; *sp*, stigmatic pores; *s*, spiracle; *sms*, submarginal seta; *vbs*, ventral body setae; *mp*, multilocular pores; *B*, tubular ducts; *C*, ventral and submarginal seta; *D*, quinquelocular pore; *E*, multilocular pore; *F*, hind leg; *G*, antenna.

Various structures of the second-instar scale, as seen in stained specimens, are shown in figure 7. The margin of the body has a fringe of setae varying slightly in distribution and number, but usually about 72. The setae are flattened at the tip, which is often emarginate or cleft, but this characteristic is less pronounced in second- than in third-instar scales. Each seta rests on a strongly chitinized tubercle set on the dorsal surface at the margin of

the body. On the ventral side of the body are minute setae varying considerably in distribution and number but set mainly submarginally and about 60 in number. The middle stigmatic seta is slightly more than three times the length of the lateral stigmatic setae. The stigmatic pores, leading from the setae to the spiracle, range in number from 7 to 12. The posterior stigmatic furrow has a slightly larger number of pores than the anterior furrow. On the ventral surface near the vagina are 3 pairs of long setae. Situated submarginally on the dorsal surface are tubercles or conelike structures, as seen in stained specimens, which give rise to the fine glassy filaments previously referred to. The dorsum of the body bears no setae or other morphological structures. The anal plates, the anal ring, and the accompanying setae are shown in figure 7, *B*. Each anal plate bears 4 apical and 2 subapical setae. There are 4 fringe and 8 anal-ring setae. Two anal-ring setae, the second pair from the dorsal side, are slender and about one-third the length of the others.

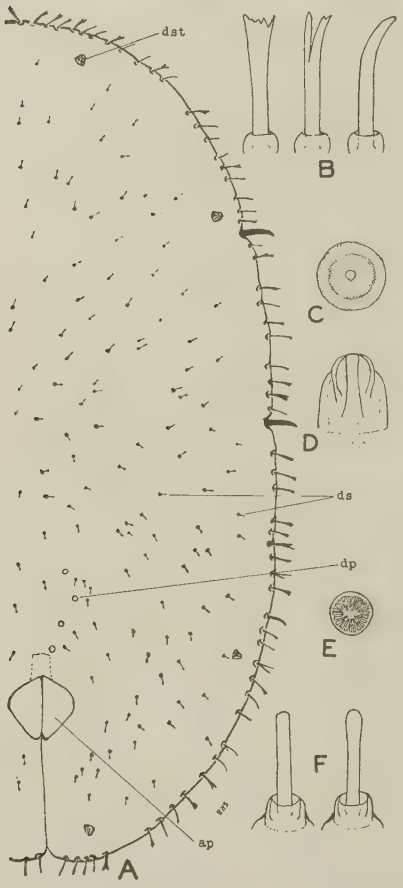

Fig. 9.—Third-instar immature nigra scale: *A*, dorsal view of part of the back: *dst*, dorsal submarginal tubercle; *ds*, dorsal setae; *dp*, dorsal pore; *ap*, anal plate; *B*, marginal setae; *C* and *D*, end view and cross-sectional side view, respectively, of dorsal submarginal tubercle; *E*, dorsal pore; *F*, dorsal setae.

Description of Third-Instar Larva.—The third-instar larva, before the period of rapid growth in March and April, may be translucent yellowish, or it may be patterned by brownish markings like those indicated in the description of the second-instar larva and shown in figure 5, *B*. During the period of rapid growth, it becomes opaque whitish, as indicated in figure 18. The insect in this stage is flat, and is commonly asymmetrical or irregular in outline. The surface of the back is relatively smooth, but fine reticulations may be seen under a microscope. The eyes appear black. Various morphological characters of the third-instar larva, as seen in stained specimens, are described below and are illustrated in figures 8, 9, 10, and 11.

Marginal setae: The marginal setae (fig. 8, *ms;* fig. 9, *B*) vary somewhat in number, distribution, position, and shape. The number is approximately 120. In some places they are spaced uniformly, but in general there is much variation in the distance between setae at different places on the margin. The shape varies from straight to curved, and from cylindrical to pointed or flattened at the end. The flattened end is emarginate or sometimes deeply incised. An occasional seta may be divided from the tip to near the base and may appear to consist of 2 distinct setae arising from a common base. Green (1904) indicated that all the marginal setae are flattened at the tip, but that since they are set edgewise, the flattening is not always apparent. Observations made in the present study do not agree with those of Green. Newstead (1903) mentions and illustrates marginal, pointed setae and setae more or less divided, situated just within the margin. The present writer believes these two types of setae mentioned by Newstead are in fact the variable marginal setae herein described and figured. Each seta arises from a cuplike structure. The setae appear to be hollow and covered with wax, as may be seen by studying living specimens under a microscope. Newstead states that the setae are connected with tubular spinnerets. The approximate

measurements of the seta are as follows: diameter 2.0μ, length 30.0μ, diameter of cuplike base 4.5μ.

Stigmatic setae: The stigmatic setae (fig. 8, *ss*) comprise four groups situated at the stigmatic clefts. Each group consists of a long median seta curved at the distal portion, and 2 short, acutely pointed lateral setae. The lateral setae are approximately one third the length of the median seta.

Submarginal and ventral body setae: On the ventral side of the body, approximately 100 minute, finely pointed setae are distributed submarginally (fig. 8, *sms*) and a smaller number are distributed elsewhere on the ventral surface (fig. 8, *vbs*). These setae vary considerably in number and position on different specimens and are not symmetrically distributed on any given specimen. The distribution shown in figure 8 is typical. An individual seta is shown at *C* in figure 8. Three pairs of long slender setae occur cephalad of the anal plates. From 2 to 4 long setae commonly occur between the bases of the antennae.

Stigmatic pores: Quinquelocular pores, ranging in number from 16 to 30, extend from the spiracle to the stigmatic cleft (fig. 8, *sp*). The structure of this type of pore is shown at *D* in figure 8. From these pores a white powdery substance is given off, which lines the spiracular groove.

Multilocular pores: Multilocular pores (fig. 8, *mp*) occur on the ventral surface of the 5 abdominal segments cephalad of the anal plates. The number of pores on a given segment varies considerably in different specimens. The segment encompassing the anal plates bears from 50 to 60 pores, and the 3 segments anteriorly in order bear approximately 14 to 20, 2 to 10, and 0 to 4 pores, respectively. Each pore appears to have 10 locules (fig. 8, *E*) and is 5μ in diameter. The pores occur in the region of the vagina and give off a white powdery substance which, in living specimens, may be seen to cover that region and also the eggs.

Tubular ducts: Scores of minute tubular ducts, visible under high magnification of carefully stained specimens, occur near the ventral surface, particularly on the posterior part of the body. Two views of a tubular duct are shown in figure 8, *B*.

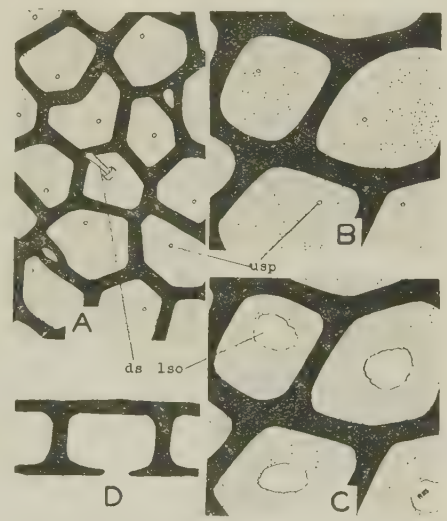

Fig. 10.—Sections of dorsal derm of third-instar nigra scale: *A*, early third-instar larva; *B* and *C*, late third-instar larva as seen with the microscope focused on the upper surface of the derm and the lower surface, respectively; *D*, cross section of a tessellation unit or cell; *ds*, dorsal seta; *usp*, upper-surface pores; *lso*, lower-surface orifice.

Dorsal submarginal tubercles: On the dorsal surface of stained specimens, submarginal tubercles may be seen distributed more or less irregularly around the edge of the body. Four such tubercles are shown in figure 9. The tubercles can be seen on adult scales by careful examination under a compound microscope. From the tubercles are produced the fine glassy filaments seen by examining living third- and second-instar larvae. The filaments are discussed in a preceding section in the description of the second-instar larva. The number of tubercles ranges from 4 or 5 to as many as 14, the usual number being 5 or 6. An end view and a cross section of a tubercle are shown in figure 9, *C* and *D*. The tubercle consists of two concentric parts, each rounded at the tip. The central part projects beyond the outer part and has a central canal through which the glassy filament is formed. The length and the width at the base are both approximately 14μ.

Dorsal setae: Scattered more or less uniformly, but not symmetrically, on the dorsum are strong blunt setae, as shown in figure 9. These setae typically are enlarged at the distal end, but a small percentage are cylindrical; the two forms are shown in figure 9, *F*. Each seta rests in a cuplike structure and appears to have a central canal which is connected with a

glandular duct. Each seta is approximately 12.0μ in length and 2.0μ in diameter, and the cuplike base is 4.5μ in diameter.

Dorsal tessellations and pores: In specimens that have been cleared and stained with acid fuchsin immediately after the second ecdysis, the dorsal derm is found to be characterized by the setae described above and by hundreds of minute clear spots. The clear spots are fairly uniformly distributed, and at the center of each clear spot is a pore. The pores are connected with ducts, which are probably glandular and produce the wax with which the dorsum of the scale becomes covered. Soon after the second ecdysis, a reticulation or tessellation of broad lines becomes evident. Each unit of the reticulation is polygonal, and contains either one clear spot and an attendant pore, or one seta, as shown in figure 10, *A*. The clear spots are variously situated within the reticulation units—seldom at the center. The reticulations are formed by a network of ridges of apodemal nature on the inner surface of the dorsum. As the test becomes more heavily sclerotized with the growth of the scale, the ridges increase in depth and form cells, and the angles of the cells become more rounded.

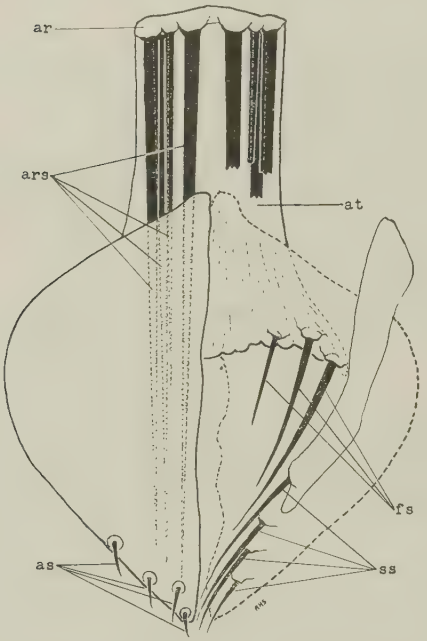

Fig. 11.—Anal plates and related structures of third-instar nigra scale: *ar*, anal ring; *ars*, anal-ring setae; *as*, apical setae; *ss*, subapical setae; *fs*, fringe setae; *at*, anal tube.

With the approach of the adult stage, the lower edges of the ridges grow laterally, so that the cells become boxlike, as shown in figure 10, *D*. In this condition the bottom side of each cell has a large circular or oval orifice (fig. 10, *C*). Viewed under high magnification, with an oil-emersion lens, the openings are seen to be irregularly circular to irregularly oval. The top side of each cell has a minute pore, as shown in figure 10, *B*. These minute pores are apparently identical with those found in the clear spots in the early third-instar larva. The ridges, openings, and pores give various optical effects when viewed under the microscope, and they vary in different specimens of scales. This variation probably accounts for differences noted by King (1902) in his characterizations of *Saissetia nigrella*, *S. nigra*, and *S. depressa*.

Dorsal pores. Cephalad of the anal plates there are 6 to 10 circular pores, each about 4.5μ in diameter. The position of these pores is indicated in figure 9. The pores occur more or less distinctly in two rows, a row extending cephalad of each anal plate. Projecting dorsally and converging above the orifice of each pore are numerous fingerlike processes that arise from the rim, as shown in figure 9, *E*.

Anal plates: The two anal plates together present a quadrangular shape, as shown in figure 11. The cephalic and caudal margins are V-shaped, and the lateral margins are rounded. The transverse and longitudinal measurements are about equal.

Anal-plate setae: The anal plates bear the two groups of setae, apical and subapical, that are characteristic of lecanine scales. Four apical setae are borne on the dorsal surface near the tip of each plate (fig. 11, *as*). Steinweden (1930) has applied the name "subdiscal" to the fourth seta from the tip. Occasional specimens may have 3 or 5 apical setae on each plate. The subapical setae (fig. 11, *ss*) are borne on the ventral side of the anal plates. Each anal plate of third-instar scales usually bears 4 subapical setae. The number is often 3, however, and rarely a scale may have 5 on one or both anal plates. Steinweden, in 1930, stated that there are 2 subapical setae, but later, upon reëxamination of his specimens, he stated that he found the number to be typically 4.[14]

[14] Steinweden, J. B., in letter to author, December 26, 1941.

Anal-fringe setae: The anal-fringe setae (fig. 11, *fs*) range from 4 to 6 in number. Some specimens have 2 setae on one side and 3 on the other.

Anal-ring setae: The anal ring bears 8 setae. Six of them are long and 2 about half the length of the long setae, as indicated in figure 11, *ars*. The anal-ring setae are notably strong.

Antennae: The antennae are typically 8-segmented. In occasional specimens some of the articulations are not distinct, and the number of segments may appear to be 7. The comparative length and chaetotaxy of the segments are indicated in figure 8, *G*. There are usually 2 setae on each of the first 2 segments, none on the third and fourth, 3 on the fifth, 1 on the sixth, 2 on the seventh, and 9 on the eighth.

Legs: The structure of the legs is typical of the lecanine scales. They are composed of 5 segments, namely, the coxa, trochanter, femur, tibia, and tarsus. At the end of the tarsus is a strong claw, and attached to the base of the claw are two stout digitules. On the dorsal side of the tarsus, near the apex, are two slender digitules. The tibiotarsal articulation is immovable. The three pairs of legs have approximately the same chaetotaxy. The hind leg is illustrated in figure 8, *F*.

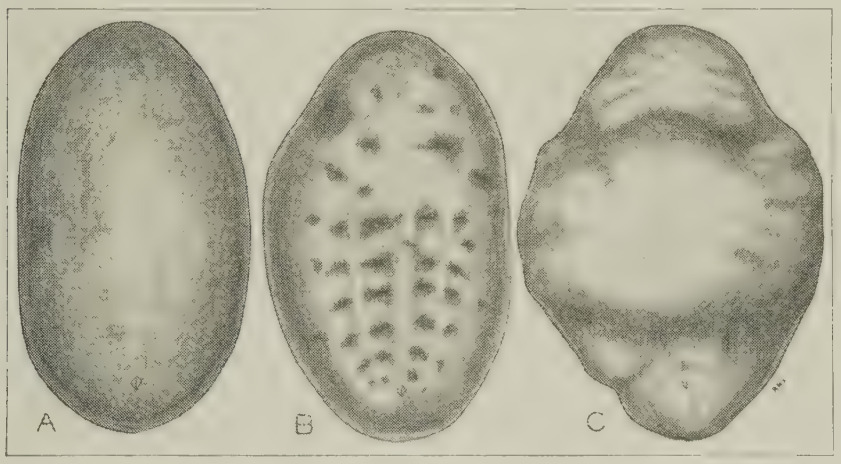

Fig. 12.—Adult nigra scales, showing variable character of the dorsum as influenced in part by the host plant: *A*, typical form of scale found on manzanita; *B*, flat form having carinae and foveae, found on many species of plants; *C*, irregular form typical of many specimens found on hibiscus in Hawaii.

Description of Third-Instar Adult.—The adult female nigra scale is notably variable in color and shape. As previously indicated, this variability was not always fully recognized by earlier writers. Dependable identification of the species should be based upon the study of microscopic mounts of stained specimens of early third-instar scales. After the test or dorsal derm has become heavily sclerotized, as in the adult scale, the structures most useful in identification cannot be seen clearly in microscopic mounts.

Color: Scales on the lower side of leaves may remain translucent yellowish for 1 or 2 months after the second ecdysis. At the beginning of the period of rapid growth in March, when the scales are 1.5 mm to 2.0 mm in length, they become opaque white. Scales on the upper side of leaves, or situated where they are exposed to considerable sunlight, may be decidedly brown as the result of a color pattern referred to in a preceding section (see "Description of Second-Instar Larva," p. 239). As the scales approach adult size, the color deepens to reddish, then quickly to brown, and finally to deep black. After a period of weeks or months, the color gradually changes again to brown, and old, dead adults may be light brown.

The many descriptions of the nigra scale occurring in the literature vary widely concerning the color of the adult scale. This is because the color varies with the age of the scale and, to some extent, with the species of host plant. On manzanita the scale is reddish brown throughout the adult stage. On *Rhus integrifolia* and *Rhus ovata*, the adults are not at first

as black as on most host plants, and the black soon changes to brown. Green (1904) states that "the colour of the mature insect varies from bright castaneous to deep purple black, the tint usually deepening with age; but examples on *Agave* and *Canna* appear to remain castaneous even when fully mature."

Shape and size: The shape and size of the adult scale are exceedingly variable, being influenced by the host species, by the plant part on which the scale develops, and by the density of the scale population. The influence of the host species on the scale was not fully recognized by the earlier writers who described the insect, and this fact explains in part why the scale has been described under six different specific names. The following statements were made by Douglas in his characterizations of the shape and size of *Lecanium nigrum*, *L. depressum*, and *L. begoniae*, later determined to be one species:

Lecanium nigrum Nietn. Scale long-oval, a little narrowed and produced in front, length 3.5 to 4 mm. (Douglas, 1887.)

Lecanium depressum Targ. Scale convex more or less according to age. Form broad-oval or ovate, sometimes one side nearly straight, or incurved so much that the outline is subreniform or subpyriform. Length 4 mm, breadth 3.5 mm. (Douglas, 1891.)

Lecanium begoniae Dougl. Scale convex, broad-ovate, or in some instances oval, being more rounded anteriorly, sides straighter, and disc humped. Length 3 to 4 mm. (Douglas, 1892.)

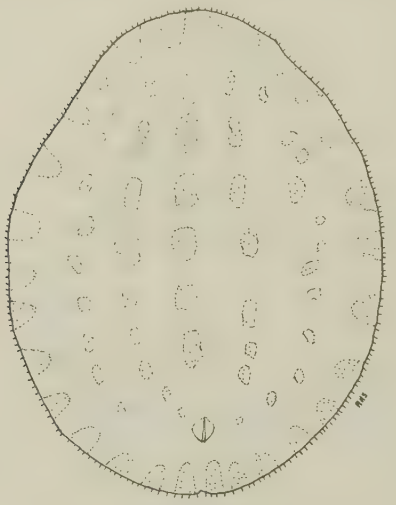

Fig. 13.—Dorsum of adult nigra scale, showing shape and distribution of wax formations, and marginal setae.

Various shapes of adult scales are shown in figures 12 and 15. The body varies from decidedly flat to strongly convex and markedly humped. The humped, irregular type (fig. 12, *C*) was found to be characteristic of specimens on the bark of hibiscus sent to the writer from Hawaii.

The dorsum may be smooth or variably uneven. Some variations in the configuration of the dorsum are shown in figure 12. The following quotations, taken from descriptions of *Saissetia nigra* and its synonyms by different writers, also indicate the variable nature of the dorsum: Nietner (1861), speaking of *S. nigra*, "Back with one longitudinal and two concentric oval costae on disc, towards the margins slightly corrugated"; Maskell (1887), of *Lecanium depressum*, "Skin marked with two dorsal keels"; Douglas (1887), of *L. depressum*, "On the anterior half on each side two mark-dotted carinae"; Douglas (1891), of *L. nigrum*, "Slightly and very briefly carinate; on the marginal area in front, on each side of the median portion a row of very small foveae (sometimes wanting)"; Cockerell (1894), of *L. begoniae*, "The scale is not equally convex in each direction; consequently, the outline as seen from the side is pyramidal, while seen from the end it is rounded"; King (1902), of *S. nigra*, "The entire outer margin carinate, distinctly so anteriorly, and posteriorly, marginally not so pronounced," and of *S. depressa*, "Surface rugose, pitted and the margin distinctly ribbed; about the center of the dorsum posteriorly is a slight but distinct depression. Marginal carina nearly obsolete"; Newstead (1903), of *L. nigrum*, "Sometimes faintly carinated in front, with the margins flat, somewhat produced, and sometimes faintly wrinkled"; and Green (1904), of *L. nigrum*, "Strongly convex, the dorsum above the abdominal region sometimes forming a pronounced hump. . . . There is often a slight median longitudinal carina and some shallow foveae on the sides."

The size of the adult scale varies so much that measurements are of little significance. On broad leaves in general, the body length of the scale ranges from 3.0 to 5.0 mm, and the width from 2.0 to 3.5 mm.

Wax formations: Patches of wax are distributed more or less regularly over the dorsum and around the margin of the body, as indicated in figure 13. These patches can be seen

particularly well on the test of old, dead scales. There are 28 patches around the margin and 5 more or less distinct longitudinal rows of patches on the main dorsal region. The marginal patches are constant in number and have the typical shape shown in figure 13. The dorsal patches vary in size, shape, and number. These wax patches have not been mentioned by previous writers. The wax can be readily lifted or broken, and on old scales it often loosens and weathers off.

TABLE 1

DISTINGUISHING CHARACTERISTICS OF ADULT LECANINE SCALES COMMONLY INFESTING ORNAMENTAL SHRUBS AND TREES IN CALIFORNIA

Species	Color	Nature of derm	Configuration of back	Reproduction
Soft (brown) scale, *Coccus hesperidum* Linn.	Variable; yellowish, brownish, grayish, or mottled	Soft, pliable	Smooth	Ovoviviparous
Elongate scale, *Coccus elongatus* (Sign.)	Grayish brown, mottled by whitish areas and about 24 waxy flecks around margin of body	Soft, pliable	Smooth	Ovoviviparous
Brown apricot scale, *Lecanium corni* Bouché	Brown	Hard, brittle	Varies with hosts; smooth or irregular	Oviparous
Hemispherical scale, *Saissetia hemisphaerica* (Targ.)	Brown	Hard, brittle	Smooth	Oviparous
Black scale, *Saissetia oleae* (Bern.)	Black to dark brown	Hard, brittle	Irregular	Oviparous
Tessellated scale, *Eucalymnatus tessellatus* (Sign.)	Black	Semihard	Smooth, with tessellations of very fine lines	Ovoviviparous
Nigra scale, *Saissetia nigra* (Nietn.)	Black to brown, with 28 wax patches around the margin of the body	Hard, brittle	Smooth or slightly rugose	Oviparous

Tessellations and papillae: Many writers have mentioned the fact that the dorsum is papillose and marked by tessellations. These characters are not always clearly visible in living specimens. They can be seen most clearly by examining the test of old, dead scales with bright light reflected from the dorsal surface, or with light passing through the test. The tessellations are produced by ridges on the inner surface of the test (fig. 10). The papillae, when present, are elevations associated with the tessellation units.

NIGRA SCALE DISTINGUISHED FROM SIMILAR SCALES INFESTING SHRUBS AND TREES IN CALIFORNIA

Seven species of lecanine scales are found more or less commonly on shrubs and ornamental trees in California. These species are the soft (brown) scale, *Coccus hesperidum* Linn.; the elongate scale, *C. elongatus* (Sign.); the hemispherical scale, *S. hemisphaerica* (Targ.); the black scale, *S. oleae* (Bern.); the nigra scale, *S. nigra* (Nietn.); the tessellated scale, *Eucalymnatus tessellatus* (Sign.); and the brown apricot scale, *Lecanium corni* Bouché. So far as has been observed in the present study, the nigra scale, the tessellated scale, and the elongate scale are found outdoors only in the coastal region. The hemispherical scale occurs much more commonly near the coast than elsewhere.

The black scale, soft (brown) scale, and brown apricot scale thrive in the warmer, more arid, interior parts of the state, as well as in the coastal region; but they occur more commonly as pests of ornamental plants in the coastal region.

The various species can usually be identified by superficial examination of the mature scales. The nigra scale resembles the tessellated scale in general appearance, and where examinations have been casual, the two species have been confused by some observers. The most obvious distinguishing characters visible to the unaided eye are revealed when the two insects are overturned. The nigra scale produces large numbers of eggs, egg laying extending over a period of months; and when all the eggs have hatched, there remains under the body a compact white mass of collapsed eggshells. The ventral part of the body is often rather colorless and has a large concavity in which the eggs accumulate until hatching takes place. The tessellated scale, on the other hand, is virtually ovoviviparous, the young emerging from a thin eggshell as soon as ejected by the parent female. The ventral side of the body of the adult tessellated scale is deep reddish and has no concavity, and the body is much flatter and thinner than that of the nigra scale. The name "tessellated" is based on the fact that the dorsal surface of the body is marked by tessellations of fine lines, readily seen on adult scales under slight magnification.

The seven species of scales may be identified fairly well with the unaided eye by the characteristics given in table 1.

HOST PLANTS OF THE NIGRA SCALE

Host Plants in California.—The nigra scale has been found on 161 species of plants in California. In the course of the present study, 137 species have been observed to be infested. The list of host plants has been compiled mainly through observations made on insect pests of ornamental shrubs and trees in the coastal region of southern California. Without doubt the list would have been much larger if the observations had been made intensively throughout the coastal region of the state. It is believed, however, that a large percentage of the preferred hosts, or those susceptible to heavy infestation, have been found. On the other hand, species that are at present susceptible to light infestation may, in the course of time, become preferred hosts; for some not infested or lightly infested in California are preferred hosts in various foreign lands.

The plants now known to be hosts of the nigra scale in California are given in table 2. The susceptibilities indicated are not considered to be invariably correct because with some hosts only a few specimens were examined. *Arctostaphylos manzanita* (manzanita), for example, is listed as being of high susceptibility because two specimens in the botanical garden of the University of California at Los Angeles became very heavily infested. Obviously, the degree of infestation of an individual plant, or a few plants in a particular restricted environment, cannot be regarded as a reliable indication of the general susceptibility of that species to infestation.

Fatsia (*Aralia*) *japonica* (Japanese aralia), *Hedera Helix, Ilex Aquifolium, Nerium Oleander,* and *Pittosporum undulatum* are definitely preferred hosts and are often very heavily infested. In scouting for the nigra

TABLE 2

HOST PLANTS OF THE NIGRA SCALE IN CALIFORNIA AND THEIR SUSCEPTIBILITY TO INFESTATION

Species of plant	Family	Susceptibility to infestation
Abutilon sp. (flowering maple)	Malvaceae	Low
Acacia sp.*	Leguminosae	—
Alpinia speciosa (shell-flower)	Zingiberaceae	Medium
Antigonon leptopus (rosa de montana)	Polygonaceae	Medium
Arbutus Unedo (strawberry-tree)	Ericaceae	Low
Arctostaphylos manzanita (manzanita)	Ericaceae	High
Asparagus plumosus (asparagus fern)	Liliaceae	Medium
Asparagus Sprengeri (Sprenger asparagus)	Liliaceae	Medium
Aucuba japonica var. *variegata* (gold dust plant)	Cornaceae	Low
Azara microphylla (boxleaf azara)	Flacourtiaceae	Medium
Beaumontia grandiflora (herald's-trumpet, Easter lily vine)	Apocynaceae	High
Begonia sp. (begonia)	Begoniaceae	Low
Berberis Thunbergii (Japanese barberry)	Berberidaceae	Low
Betula alba (European white birch)*	Betulaceae	—
Buxus microphylla var. *japonica* (Japanese box)	Buxaceae	Low
Callistemon viminalis (weeping callistemon)	Myrtaceae	High
Calluna vulgaris (common, or Scotch, heather)*	Ericaceae	—
Camellia japonica (camellia)	Theaceae	Low
Carissa grandiflora (Natal plum)	Apocynaceae	Medium
Casimiroa edulis (white sapote)	Rutaceae	High
Casimiroa tetrameria (woollyleaf white sapote)	Rutaceae	High
Cassia nairobensis	Leguminosae	Low
Cedrus Deodara (deodar cedar)	Pinaceae	Low
Ceratonia Siliqua (carob)	Leguminosae	Low
Cestrum aurantiacum (orange cestrum)	Solanaceae	Low
Cestrum nocturnum (night jasmine)	Solanaceae	Low
Choisya ternata (Mexican-orange)	Rutaceae	Low
Chorizema cordatum	Leguminosae	Low
Chrysanthemum fructescens (marguerite)*	Compositae	—
Citrus Limonia (lemon)	Rutaceae	Low
Citrus paradisi (grapefruit)	Rutaceae	Low
Citrus sinensis (orange)	Rutaceae	Low
Cocculus laurifolius	Menispermaceae	Medium
Coprosma Baueri (coprosma)	Rubiaceae	Low
Correa speciosa (*C. pulchella*) (Australian fuchsia)	Rutaceae	Medium
Cotoneaster Franchetii	Rosaceae	Low
Cotoneaster pannosa	Rosaceae	Low
Cotoneaster Parneyi	Rosaceae	Low
Cotoneaster salicifolia	Rosaceae	Low
Crassula arborescens	Crassulaceae	Low
Cycas revoluta (sago cycas)	Cycadaceae	Low
Cytisus (*Genista*) *fragrans*	Leguminosae	Low
Cytisus scoparius (*Genista scoparia*) (Scotch broom)	Leguminosae	Low
Dieffenbachia sp. (tuftroot)*	Araceae	
Dovyalis caffra (kei-apple)	Flacourtiaceae	High
Duranta Plumieri (golden dewdrop)	Verbenaceae	Medium
Equisetum sp. (horsetail)	Equisetaceae	Low
Eriobotrya japonica (loquat)	Rosaceae	Low
Escallonia rubra	Saxifragaceae	Medium
Eucalyptus ficifolia (scarlet-flowering eucalyptus)	Myrtaceae	Low
Eucalyptus viminalis (manna gum)	Myrtaceae	Low
Eugenia Hookeri	Myrtaceae	Medium
Eugenia Jambos (rose-apple)	Myrtaceae	Low
Eugenia paniculata var. *australis* (*E. myrtifolia*)	Myrtaceae	Medium
Eugenia uniflora (Surinam cherry)	Myrtaceae	Low

* Plants recorded as hosts by the Agricultural Commissioner of Los Angeles County.

TABLE 2 (*Continued*)

Species of plant	Family	Susceptibility to infestation
Euonymus japonicus	Celastraceae	Medium
Euphorbia sp.	Euphorbiaceae	Low
Fatsia (*Aralia*) *japonica* (Japanese aralia)	Araliaceae	High
Feijoa Sellowiana (feijoa, pineapple guava)	Myrtaceae	Low
Ficus Carica (fig)	Moraceae	Low
Ficus pumila (creeping fig)	Moraceae	Low
Ficus pumila var. *minima* (small-leaf creeping fig)	Moraceae	Low
Fuchsia sp.	Onagraceae	Low
Gardenia sp.*	Rubiaceae	—
Grevillea Thelemanniana (hummingbird bush)	Proteaceae	Low
Grewia caffra	Tiliaceae	Low
Harpephyllum caffrum (kafir plum)	Anacardiaceae	High
Harpullia arborea	Sapindaceae	Low
Hedera canariensis (Algerian ivy)	Araliaceae	High
Hedera Helix (English ivy)	Araliaceae	High
Hedera Helix var. *conglomerata*	Araliaceae	Low
Hedera Helix var. *gracilis* (small-leaved ivy)	Araliaceae	Low
Hedera Helix var. *hibernica* (Irish ivy)	Araliaceae	Low
Heliconia sp.*	Musaceae	—
Hibiscus sp.*	Malvaceae	—
Howea (*Kentia*) *Forsteriana* (Kentia palm)	Palmaceae	Low
Ilex Aquifolium (English holly)	Aquifoliaceae	High
Ilex Cassine (dahoon holly)	Aquifoliaceae	Medium
Ilex cornuta (Chinese holly)	Aquifoliaceae	Medium
Ilex pedunculosa (*I. fujisanensis*) (Japanese holly)	Aquifoliaceae	High
Iochroma lanceolatum	Solanaceae	Low
Iris unguicularis (*I. stylosa*) (winter iris)	Iridaceae	Low
Itea ilicifolia	Saxifragaceae	High
Laurus nobilis (sweet bay)	Lauraceae	Low
Leptospermum laevigatum (Australian tea tree)	Myrtaceae	Low
Ligustrum sp. (privet)*	Oleaceae	—
Litchi chinensis (litchi)	Sapindaceae	Medium
Lucuma mammosa (sapote)	Sapotaceae	Medium
Macadamia ternifolia (Queensland nut)	Proteaceae	Low
Mackaya bella	Acanthaceae	Medium
Mahonia Aquifolium (Oregon grape)	Berberidaceae	Low
Mahonia japonica (Japanese mahonia)	Berberidaceae	Medium
Malus sylvestris (apple)*	Rosaceae	—
Mangifera indica (mango)	Anacardiaceae	Medium
Maytenus boaria	Celastraceae	Medium
Melaleuca decussata (bottle-brush)	Myrtaceae	Low
Monstera deliciosa	Araceae	Medium
*Morea bicolor**	Iridaceae	—
Morea iridioides	Iridaceae	Medium
Muehlenbeckia platyclados	Polygonaceae	Low
Musa paradisiaca var. *sapientum* (banana)	Musaceae	Low
Myoporum laetum	Myoporaceae	Low
Nandina domestica	Berberidaceae	Medium
Nephrolepis sp. (sword fern)	Polypodiaceae	Low
Nephrolepis exaltata var. *bostoniensis* (Boston fern)	Polypodiaceae	Low
Nerium Oleander (oleander)	Apocynaceae	High
Olea europaea (olive)	Oleaceae	Low
Orchid*	Orchidaceae	—
Osmanthus ilicifolius	Oleaceae	Low
Pandorea pandorana (*Tecoma australis*) (wonga-wonga vine)	Bignoniaceae	Medium
Parthenocissus (*Ampelopsis*) *quinquefolia* (Virginia creeper)	Vitaceae	Low
Passiflora sp. (passion-flower)	Passifloraceae	Low
Persea americana (avocado)	Lauraceae	Low
Phalaris arundinacea (reed canary-grass)*	Gramineae	—

* Plants recorded as hosts by the Agricultural Commissioner of Los Angeles County.

TABLE 2 (*Concluded*)

Species of plant	Family	Susceptibility to infestation
Philadelphus mexicanus (Mexican mock-orange)	Saxifragaceae	Low
Philodendron sp.*	Araceae	—
Phoenix reclinata (palm)	Palmaceae	Low
Photinia (*Heteromeles*) *arbutifolia* (California holly, toyon)	Rosaceae	Medium
Photinia serrulata (Chinese photinia)	Rosaceae	Low
Pinus sp.	Pinaceae	Low
Pistacia sp. (pistachio nut)	Anacardiaceae	Low
Pittosporum crassifolium	Pittosporaceae	Medium
Pittosporum eugenoides	Pittosporaceae	High
Pittosporum phillyraeoides	Pittosporaceae	Medium
Pittosporum rhombifolium	Pittosporaceae	Low
Pittosporum tenuifolium (*P. nigricans*)	Pittosporaceae	Medium
Pittosporum Tobira	Pittosporaceae	Low
Pittosporum undulatum	Pittosporaceae	High
Platanus orientalis (Oriental plane tree)	Platanaceae	Low
Populus sp.*	Salicaceae	—
Prunus Armeniaca (apricot)*	Rosaceae	—
Prunus domestica (plum)*	Rosaceae	—
Prunus Lyonii (*P. ilicifolia*) (Catalina cherry)*	Rosaceae	—
Prunus Persica (peach)*	Rosaceae	—
Psidium sp. (guava)	Myrtaceae	Medium
Pyracantha sp.	Rosaceae	Low
Rhamnus californica (California coffeeberry)	Rhamnaceae	Low
Rhapis sp. (Rhapis palm)	Palmaceae	Medium
Rhododendron sp.*	Ericaceae	—
Rhus integrifolia (lemonade berry)	Anacardiaceae	High
Rhus ovata	Anacardiaceae	High
Sassafras sp.*	Lauraceae	—
Schinus Molle (California pepper tree)	Anacardiaceae	Low
Schinus terebinthifolius (Brazilian pepper tree)	Anacardiaceae	High
Sedum sp.	Crassulaceae	Low
Sequoia sempervirens (redwood)*	Pinaceae	—
Solandra guttata (cup of gold)	Solanaceae	Low
Solanum muricatum (pepino)	Solanaceae	Low
Solanum Rantonnetii	Solanaceae	Low
Sollya heterophylla (Australian bluebell creeper)	Pittosporaceae	Medium
Spiraea sp.*	Rosaceae	—
Strelitzia Nicolai (bird-of-paradise flower)	Musaceae	Low
Strelitzia Reginae (bird-of-paradise flower)	Musaceae	Medium
Tecomaria (*Tecoma*) *capensis* (Cape-honeysuckle)	Bignoniaceae	Medium
Thevetia nereifolia (yellow oleander)	Apocynaceae	Medium
Trachelospermum jasminoides (star-jasmine)	Apocynaceae	Low
Tristania conferta	Myrtaceae	Medium
Umbellularia californica (California laurel)	Lauraceae	Low
Veronica sp.	Scrophulariaceae	Low
Yucca sp.	Liliaceae	Low

* Plants recorded as hosts by the Agricultural Commissioner of Los Angeles County.

scale, *I. Aquifolium* has been found the best key plant in the region from Monterey County northward to Sonoma County, *P. undulatum* and *Hedera* spp. the best from Monterey County southward to San Diego County. *P. eugenoides* is definitely less susceptible to heavy infestation than is *P. undulatum*, but several heavy infestations of the former have been observed. *Eugenia paniculata* var. *australis* (*E. myrtifolia*) and *E. paniculata* (*E. Hookeri*) are commonly infested, but only rarely has the scale been observed on them in large numbers.

Many plants listed in the category of low susceptibility are extraordinarily

casual hosts. Among them are *Acacia* sp., *Cedrus Deodara* (deodar cedar), *Ceratonia Siliqua* (carob), *Coprosma Baueri, Cytisus* (genista), *Eucalyptus, Ficus Carica* (fig), *Fuchsia, Hibiscus, Leptospermum laevigatum, Ligustrum* sp. (privet), *Malus sylvestris* (apple), *Olea europaea* (olive), *Persea americana* (avocado), *Pinus, Pittosporum Tobira, Platanus orientalis* (Oriental plane tree), *Prunus Armeniaca* (apricot), *Prunus domestica* (plum), *Prunus Lyonii* (Catalina cherry), *Prunus Persica* (peach), *Sequoia sempervirens* (redwood), *Spiraea,* and *Veronica.* These species have been repeatedly observed growing in contact with heavily infested plants, or in close proximity to them, but only rarely has a specimen of nigra scale been found.

Host Plants Reported outside California.—Outside California approximately 148 species of plants have been recorded as hosts of the nigra scale. Since the scale is notably polyphytophagous, there is reason to believe that the recorded hosts represent but a small percentage of the total number of species susceptible to infestation. Of all the accounts reviewed, only two give particular consideration to the number or diversity of species of plants found to be infested. Green (1904) lists 20 species infested in Ceylon, and Takahashi (1929) 26 species infested in Formosa. South (1913) states that the scale occurs on many plants in the West Indies, but he names only 7 species. Bodkin (1917) states that the nigra scale is the most common species of *Saissetia* in British Guiana. He names 4 host species and says that the insect infests many others. Of approximately 148 species of host plants recorded outside California, 10 are listed as having been found infested in greenhouses in various parts of the United States, 6 are listed from Florida, and 14 from the Hawaiian Islands. Only 22 of those recorded elsewhere have been found infested in California. The species of host plants reported from outside California, and the region, or some of the regions, where each species has been reported, are presented in table 3.

Characteristics of Preferred Hosts.—The species of plants on which the nigra scale thrives in great abundance appear to have in common no particular characteristic that is evident through outward observation. Susceptibility to heavy infestation is probably determined more by physiological characteristics of the host plant than by morphological ones. Targioni (1867) stated that the scale infested *Ficus* and other plants having leathery leaves. That characterization has a limited significance as far as it may imply plants having thick leaves. *Nerium Oleander, Hedera* spp., *Rhus integrifolia, Dovyalis caffra, Ilex* spp., and *Fatsia* (*Aralia*) *japonica,* all have thick leaves and are commonly heavily infested. On the other hand, the leaves of *Pittosporum undulatum* are not particularly thick, yet this species ranks near the top among the preferred hosts. The leaves of *Fatsia japonica* are rather succulent, while the leaves of *Ilex* are notably hard and brittle. One flourishing infestation was observed on a palm, *Phoenix reclinata,* the leaves of which are notably thin and nonsucculent. Plants having broad leaves and smooth bark on the smaller branches are among the preferred hosts, although *Callistemon viminalis,* which has narrow leaves, is sometimes very heavily infested.

Diversity in the Species and Botanical Nature of Plants Attacked.—So far as was observed in the present study, the nigra scale attacks a greater variety of plants than the soft (brown) scale and the hemispherical scale. These three

TABLE 3

HOST PLANTS ON WHICH THE NIGRA SCALE HAS BEEN RECORDED OUTSIDE CALIFORNIA

Species of plant	Family	Location of infestation
Abutilon sp.	Malvaceae	Ceylon
Adiantum (maidenhair fern)	Polypodiaceae	Washington, D.C.
Agave sp.	Amaryllidaceae	Java, Philippine Islands
Agave americana (century plant)	Amaryllidaceae	Ceylon
Amygdalus (*Prunus*) *communis* (almond)	Rosaceae	St. Vincent
Ananas Comosus (*A. sativus*) (pineapple)	Bromeliaceae	Hawaii
Annona cherimola (cherimoya)	Annonaceae	Australia, Ceylon, West Indies
Annona muricata (soursop)	Annonaceae	Uganda
Annona squamosa (sweetsop)	Annonaceae	Antilles, St. Vincent
Anthurium sp.	Araceae	United States
Antigonon sp.	Polygonaceae	Pennsylvania
Aralia sp.	Araliaceae	Japan
Ardisia pentagona (*A. quinquegona*)	Myrsinaceae	Formosa
Areca catechu (betel palm)	Palmaceae	Hawaii, Japan, Formosa
Artemisia capillaris	Compositae	Formosa
Asparagus sp.	Liliaceae	Lesser Antilles, India
Asparagus falcatus	Liliaceae	Ceylon
Bambusa sp. (bamboo)	Gramineae	Hawaii, East Indies
Begonia sp.	Begoniaceae	Lesser Antilles, Ceylon, Hawaii, British Guiana
Bischofia javanica	Euphorbiaceae	Formosa
Boehmeria densiflora	Urticaceae	Japan
Bougainvillea sp.	Nyctaginaceae	Hawaii
Brassia sp. (spider orchid)	Orchidaceae	Hawaii
Bromelia sp.	Bromeliaceae	Hawaii
Bryophyllum sp.	Crassulaceae	Hawaii
Caladium sp.	Araceae	Hawaii
Calathea (*Maranta*) *zebrina*	Marantaceae	Ceylon
Calonyction (moonflower)	Convolvulaceae	Washington, D.C.
Calophyllum inophyllum	Guttiferaceae	Formosa
Camellia sp.	Theaceae	England
Canna sp.	Cannaceae	Malaya
Canna indica	Cannaceae	Formosa
Carica Papaya (papaya)	Caricaceae	Lesser Antilles, St. Vincent, Queensland, Florida
Ceiba pentandra (silk-cotton tree)	Bombacaceae	Java, Malaya
Celtis panicatata	Ulmaceae	New South Wales
Celtis sinensis	Ulmaceae	Japan
Chrysanthemum sp.	Compositae	Hawaii
Chrysophyllum Cainito (star-apple)	Sapotaceae	Formosa
Cinchona sp.	Rubiaceae	Ceylon
Cinchona officinalis (medicinal cinchona)	Rubiaceae	Ceylon, South America
Cinchona succirubra (redbark cinchona)	Rubiaceae	Ceylon, South America
Cinnamomum Camphora (camphor)	Lauraceae	Washington, D.C.
Citrus sp.	Rutaceae	Queensland, South Africa, Egypt, Washington, D.C., Bermuda, New South Wales, Mozambique, Formosa
Citrus aurantifolia (lime)	Rutaceae	Bermuda
Citrus sinensis (orange)	Rutaceae	Queensland
Cobaea sp.	Polemoniaceae	Lesser Antilles, Ceylon
Cobaea scandens	Polemoniaceae	Ceylon
Cocos nucifera (coconut)	Palmaceae	Hawaii, India
Codiaeum variegatum (croton)	Euphorbiaceae	Hawaii, Formosa
Coffea sp. (coffee)	Rubiaceae	East Indies, British East Africa, Jamaica, Kenya, Malaya, Bolivia, Salvador, Belgian Congo, Ceylon, India

TABLE 3 (*Continued*)

Species of plant	Family	Location of infestation
Coffea liberica (Liberian coffee)	Rubiaceae	El Salvador
Coleus sp.	Labiatae	Hawaii, West Indies
Colocasia sp.	Araceae	Hawaii
Combretum Aubletii	Combretaceae	British Guiana
Cordyline terminalis (common dracena)	Liliaceae	Hawaii
Croton Tiglium (croton-oil plant)	Euphorbiaceae	Ceylon, British Guiana, Hawaii, Malaya, India
Cypripedium Argus	Orchidaceae	India
Cypripedium venustum	Orchidaceae	India
Cypripedium villosum	Orchidaceae	India
Dahlia sp.	Compositae	Ceylon
Dieffenbachia sp. (tuftroot)	Araceae	Hawaii
Dracaena sp.	Liliaceae	Hawaii
Eremocitrus sp.	Rutaceae	Australia, Queensland
Erythrina sp. (dádap)	Leguminosae	Malaya
Eugenia javanica	Myrtaceae	Formosa
Eugenia malaccensis (Malay apple)	Myrtaceae	Salvador
Euphorbia pulcherrima (poinsettia)	Euphorbiaceae	Ceylon, Hawaii
Ferns	.....	Hawaii
Ficus sp.	Moraceae	Natal, Ceylon, British Guiana, Tanganyika Territory, St. Vincent, Lower California, Seychelles, St. Thomas, Sumatra, La Paz, Malaya, New York, Egypt, Florida, Italy
Ficus Carica (fig)	Moraceae	Egypt, Formosa, South Africa, West Indies
Ficus elastica (rubber plant)	Moraceae	Florida, France, England, Formosa
Ficus gibbosa	Moraceae	Formosa
Ficus laurifolia (*F. marticinensis*)	Moraceae	Italy
Ficus retusa	Moraceae	Formosa
Ficus Sycómorus	Moraceae	Egypt
Ficus Wrightiana	Moraceae	Formosa
Fig (wild)	Moraceae	Barbados
Flacourtia sapida	Flacourtiaceae	Africa
Furcraea sp.	Amaryllidaceae	West Indies
Gardenia sp.	Rubiaceae	Hawaii
Gerberia Jamesonii (gerbera)	Compositae	Hawaii
Glochidion sp.	Euphorbiaceae	Formosa
Gossypium sp. (cotton)	Malvaceae	West Indies, Africa, British Guiana, Dutch East Africa, Ceylon, Jamaica, Trinidad, India, Antigua, St. Vincent, Bombay, North Bihar, Fiji, Virgin Islands, Ecuador, Malaya, Tanganyika Territory, Puerto Rico, Hawaii, Japan, Formosa
Gossypium herbaceum (Levant cotton)	Malvaceae	Formosa
Graptophyllum sp.	Acanthaceae	Ceylon, Hawaii
Hakea sp. (needle bush)	Proteaceae	New South Wales
Heliconia metallica	Musaceae	Brazil
Hevea brasiliensis (Pará rubber tree)	Euphorbiaceae	Seychelles, Ceylon, British Guiana, India, Dutch Indies, Malaya
Hevea guianensis	Euphorbiaceae	St. Thomas, Ceylon, Sumatra

TABLE 3 (*Continued*)

Species of plant	Family	Location of infestation
Hibiscus sp.	Malvaceae	Malaya, Florida, Labuan Islands, Samoa, Swains Island, New Hebrides, Hawaii, West Indies
Hibiscus Rosa-sinensis	Malvaceae	Lesser Antilles, Ceylon, Seychelles, St. Vincent, Hawaii, Siam, Samoa, Ohio
Hibiscus Sabdariffa (roselle)	Malvaceae	Malaya
Inga sp.	Leguminosae	Africa
Ipomoea tuberosa	Convolvulaceae	Hawaii
Ixora sp.	Rubiaceae	Hawaii
Jatropha sp.	Euphorbiaceae	Ceylon
Justicia Macdonaldii	Acanthaceae	British Guiana
Kigelia pinnata (sausage tree)	Bignoniaceae	Hawaii
Laurus nobilis (sweet bay)	Lauraceae	Florida
Loranthus Exocarpi (mistletoe)	Loranthaceae	New South Wales
Malvaviscus arboreus (Turk's cap)	Malvacea	Florida
Mangifera indica (mango)	Anacardiaceae	Zanzibar, Florida
Manihot Glaziovii (Ceará rubber)	Euphorbiaceae	Ceylon, Lesser Antilles, Africa, India, South America
Manihot esculenta (*M. utilissima*) (cassava)	Euphorbiaceae	Ceylon, Philippine Islands
Maranta sp.	Marantaceae	Ceylon
Maranta zebrina	Marantaceae	Ceylon
Morus sp. (mulberry)	Moraceae	Formosa
Morus alba	Moraceae	Formosa
Musa sp. (banana)	Musaceae	England, Hawaii
Musa paradisiaca var. *sapientum* (banana)	Musaceae	Formosa, Hawaii, Central America, South America, West Indies
Mussaenda frondosa	Rubiaceae	Ceylon
Orchid	Orchidaceae	Guatemala
Osteospermum moniliferum	Compositae	New South Wales
Palm	Palmaceae	Australia, Hawaii
Peristrophe	Acanthaceae	Washington, D.C.
Persea americana (avocado)	Lauraceae	South Africa, Trinidad, Tobago
Prunus sp. (wild almond)	Rosaceae	Barbados
Phalaenopsis Aphrodite	Orchidaceae	Philippine Islands
Phalaenopsis Schilleriana	Orchidaceae	Philippine Islands
Piper betle	Piperaceae	Hawaii
Pittosporum sp.	Pittosporaceae	Hawaii
Plectronia parviflora	Rubiacea	Ceylon
Pluchea odorata	Compositae	United States
Plumeria sp. (frangipani)	Apocynaceae	Hawaii
Plumeria rubra var. *acutifolia*	Apocynaceae	Formosa
Prunus communis (almond)	Rosaceae	St. Vincent
Psidium Guajava (guava)	Myrtaceae	West Indies, Formosa
Pyrus sp.	Rosaceae	Formosa
Rhamnus crocea (redberry)	Rhamnaceae	Hawaii
Rhipsalis Cassytha (mistletoe-cactus)	Cactaceae	Guatemala
Ricinus communis (castor-oil plant)	Euphorbiaceae	Seychelles, India
Rosa (rose)	Rosaceae	Washington, D.C.
Rumex (sorrel)	Polygonaceae	Barbados
Saliz Warburgii	Salicaceae	Formosa
Salpichroa rhamboidea (*Withania origanifolia*) (cock's egg)	Solanaceae	Philippine Islands
Santalum sp. (sandalwood)	Santalaceae	India
Sapium Jenmanii (native rubber tree)	Euphorbiaceae	British Guiana
Sapium sebiferum	Euphorbiaceae	Formosa
Schinus Molle (California pepper tree)	Anacardiaceae	Egypt, Hawaii, Queensland

TABLE 3 (*Concluded*)

Species of plant	Family	Location of infestation
Schinus terebinthifolius (Brazilian pepper tree)	Anacardiaceae	Hawaii
Solanum Melongena (eggplant)	Solanaceae	Japan, Lesser Antilles
Spondias Mombin (hog-plum)	Anacardiaceae	Lesser Antilles
Sterculia sp.	Sterculiaceae	United States
Strelitzia sp.	Musaceae	Hawaii
Tectona grandis (teak)	Verbenaceae	Lesser Antilles, East Indies
Terminalia Catappa (tropical almond)	Combretaceae	West Indies, Japan, Formosa
Thea sp. (tea)	Theaceae	Malaya
Thespesia populnea (portia tree)	Malvaceae	Ceylon
Vitis sp.	Vitaceae	Ceylon, New South Wales
Vitis vinifera (wine grape)	Vitaceae	Egypt, Australia
Wood rose	.....	Hawaii
Zizyphus Spina-Christi	Rhamnaceae	Egypt

scales infest a notably large number of species of ornamental shrubs and trees in California. The nigra scale greatly outranks the black scale in the diversity of ornamental plants attacked.

Approximately 287 species of plants, distributed in 77 families, are listed herein as hosts of the nigra scale. The plants represent a wide diversity in botanical nature. They are distributed in the pteridophytes, the gymnosperms, and angiosperms.

The number of species of pteridophytes found infested is small. They include maidenhair fern (*Adiantum* sp.), Boston fern (*Nephrolepis exaltata* var. *bostoniensis*), and horsetail, or scouring rush (*Equisetum* sp.). Six authors list fern as a host but do not name the genus or species. The infestation on scouring rush was observed near Watsonville, California, on plants growing about 10 feet away from a heavily infested thicket of *Pittosporum eugenoides*.

The species of gymnosperms on which the nigra scale has been observed in the present study include deodar cedar (*Cedrus Deodara*) and sago cycas (*Cycas revoluta*). The scale has been recorded on *Pinus* sp. and redwood (*Sequoia sempervirens*) in nursery inspections made by the Los Angeles County Agricultural Commissioner.

The host plants among the angiosperms are distributed in 74 families. In the family Rosaceae, 18 species have been found to be hosts of the nigra scale; in the Euphorbiaceae, 15; in the Myrtaceae, 12; in the Moraceae, 10; in the Araliaceae, 9; and 8 in each of the families Malvaceae, Pittosporaceae, Rubiaceae, and Rutaceae. The number of species recorded in a given family does not necessarily indicate the relative susceptibility of the particular family to attack. On the contrary, the number of species may reflect the abundance of species of a particular family in the region or regions where the scale has been studied. Of the 18 species of hosts in the family Rosaceae, 17 must be regarded as very casual hosts and rarely infested. Several preferred host species occur in each of the other families mentioned above. Among the diverse families of angiosperms that are hosts of the nigra scale are the Gramineae (grasses, bamboos), Palmaceae (palms), Cactaceae (cactus), Vitaceae (various vines), and the many families represented by species of herbaceous host plants.

Adaptation to Plants Uncommonly Infested: Evidence of Host-Specific Strains.—Particularly interesting has been the discovery of flourishing infes-

tations of nigra scale on occasional plants of species supposed to be immune to infestation. The study of such infestations has evoked the hypothesis that physiological strains or host specific forms of the scale have given rise to the infestations. Since the nigra scale reproduces parthenogenetically, the establishment of host-specific variants would be more readily effected than in the case of species having sexual reproduction. The subject has an important bearing upon the question whether the nigra scale is a potential pest of importance to citrus and avocado trees in California. Infestations of this nature, observed during three years of intensive study of the scale, occurred on *Pittosporum Tobira, Eucalyptus ficifolia* (scarlet-flowering eucalyptus), and *Arctostaphylos manzanita.*

The examination of dozens of specimens of *Pittosporum Tobira* that were growing in direct contact with, or in very close proximity to, heavily infested plants of *P. undulatum* and other preferred hosts, had led to the assumption that *P. Tobira* was immune to infestation. Particular interest was given to a search for the scale on *P. Tobira*, because, of seven widely grown species of *Pittosporum,* all except *P. Tobira* are hosts of the nigra scale, and two of the most common species, *P. undulatum* and *P. eugenoides,* are preferred hosts. In September, 1938, one adult nigra scale was found on a *P. Tobira* plant that was growing directly under a large, heavily infested plant of *P. undulatum* known to have been heavily infested the preceding two years. It is believed that many millions of crawlers had settled on the *P. Tobira* plant and, of that entire number, only one individual had developed to maturity. The scale was normal in size and general appearance. Inadvertently, the leaf bearing the scale was picked and taken to the laboratory for preservation as a novelty. Most of the eggs had been laid and had hatched, however, and the resultant crawlers had settled on the leaves. The following year a light infestation occurred on the same plant on which the mature scale had been found. This infestation, along with those on other hosts generally, completely died out during the autumn of 1939 as a result of natural causes.

In the late summer of 1939, a very light infestation of nigra scale was found on two trees of *Eucalyptus ficifolia* growing side by side on Sunset Boulevard in West Los Angeles. This is the only infestation found by the writer on *Eucalyptus.* A native shrub, *Rhus integrifolia*, occurred in large numbers along the row of *Eucalyptus* and was known to have been heavily infested continously for three years. The scales on the *Eucalyptus* were notably fine specimens (fig. 14). As with *Pittosporum Tobira*, this infestation died out completely in the autumn of 1939 as a result of natural causes.

During 1938 and 1939 a heavy infestation of nigra scale occurred on two plants of *Arctostaphylos manzanita* growing in the botanical garden of the University of California at Los Angeles. Many of the branches were so densely covered with the scale that scarcely a trace of the bark was visible. This is the only instance in which the scale was found on the species, notwithstanding the fact that a search was made of a large number of plants in other locations, some of them growing among heavily infested plants of *Rhus integrifolia* and *R. ovata.*

In some parts of the world, particularly in the Hawaiian Islands, *Hibiscus* is a preferred host of the nigra scale. In the earlier literature the insect was

sometimes called the hibiscus shield scale. The writer has never found even one specimen of the scale on this ornamental in California, even on plants growing in close contact with heavily infested hosts. For two years, observations were made of a hibiscus that was growing with its branches interlaced with a heavily infested specimen of *Pittosporum undulatum*. The absence of nigra scale on *Hibiscus* in California tends to indicate that there exists in the Hawaiian Islands a host-specific form or a strain that has not yet become established in California.

Many attempts were made experimentally to infest *Pittosporum Tobira, Eucalyptus ficifolia, Arctostaphylos manzanita,* and *Hibiscus*. In these experiments large numbers of eggs were placed on the foliage. The crawlers settled in large numbers but soon died.

HABITAT RELATIONS

The nigra scale thrives under a wide range of environmental conditions. Heavy infestations have long existed on *Pittosporum undulatum* and *Fatsia* (*Aralia*) *japonica* under densely shaded, humid conditions in a garden in West Los Angeles. Within a mile of that place equally heavy infestations have existed on *Rhus integrifolia* growing under arid conditions in the native chaparral, and on *P. undulatum* growing in dry parkings that border asphalt-surfaced streets and cement sidewalks. In the latter locations the insects are subject to intense light and high temperature. For a period of at least four years heavy infestations were common on the native shrub, *R. integrifolia,* along the arid foothills above Pasadena and along the foothills of the Santa Monica Mountains. In the southern part of the state, the insect favors the shaded portions of the plants, and tends to occur in greatest numbers on the inner leaves and branches, and on the north side of trees and shrubs. In the San Francisco Bay region, particularly in Alameda, Oakland, and San Rafael, the infestations have seemed to be fairly uniform on all parts of the hosts. The insect thrives especially in greenhouses and lath-houses. In general, the scales that develop on plants in enclosed places are more robust than those that develop in warm, dry, outdoor habitats.

CHARACTERISTICS OF INFESTATION

The nigra scale is principally a leaf-infesting species, but on some kinds of plants it freely infests the smooth bark. The distribution of the adult scales on the leaves varies with the host plant and exposure. Typically, the scales occur on the lower side of the leaves, but where the host plant is well shaded the two sides may be infested equally. With infestations on *Ilex* plants in unshaded situations, a large percentage of the scales may occur on the upper side of the leaves. With infestations on unshaded aralia plants, nearly all the scales occur on the lower side. On most kinds of plants, but especially on *Pittosporum* spp. (fig. 14, *A–C*), *Rhus* spp., and *Nerium Oleander,* there is a marked tendency for the scales to be concentrated along each side of the midrib of the leaf. On plants of *Hedera* spp. the scales tend to be distributed generally over the leaf (fig. 17). The infestation found on the leaves of *Eucalyptus ficifolia* (p. 257) was particularly interesting because the scales were widely dispersed on the leaf and many occurred close to the margin (fig. 14, *D*).

With infestations on *Ilex* spp., *Euonymus* sp., *Carissa grandiflora, Rhus integrifolia,* and *R. ovata,* a large percentage of the adult scales occur on the smooth bark. The heavy infestation observed on the two *Arctostaphylos manzanita* plants in the botanical garden of the University of California at Los

Fig. 14.—Infestations of nigra scale on various plants: *A,* adult scales on leaves of *Pittosporum undulatum; B,* lower surface of pittosporum leaf bearing 26 adult and 986 young scales, photographed in August; *C,* adult scales photographed in June before hatching began; *D,* adult scales on leaf of *Eucalyptus ficifolia; E, F,* and *G,* infestations on *Schinus Molle, Hibiscus* (from Hawaii), and *Rhus integrifolia,* respectively.

Angeles, previously referred to, was notable because nearly all the adult scales occurred on the bark. Rarely does a scale occur on the large, green petioles of aralia leaves, even where the blades of the leaves are heavily infested. Oleander leaves may bear thousands of scales, but very few scales will

be found on the smooth bark. With heavy infestations on *Schinus terebinthifolius* (Brazilian pepper tree) and on *S. Molle* (California pepper tree) nearly all the mature scales occur on the smooth bark of the smaller branches. The bark of the terminal branches of *Pittosporum* appears to be as smooth as the infested bark of some other plants, yet seldom are scales found on the bark of *Pittosporum*.

Under conditions of light infestation, the scales may be restricted in distribution mostly to a particular branch or to parts of a shrub or tree. This type of infestation is also characteristic of the soft (brown) scale and the elongate scale. In infestations by these two species, however, the scales usually occur in all stages of development, whereas in infestations by the nigra scale all the individuals are in nearly the same stage at any given time. The nigra scale is commonly attended by ants, but less so than is the soft (brown) scale.

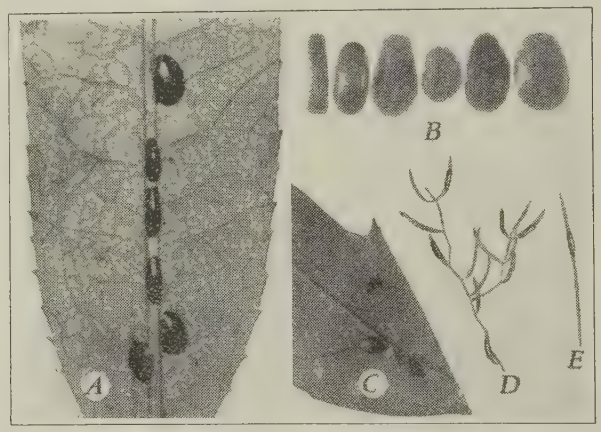

Fig. 15.—The effect of the host on the shape and size of the nigra scale: *A*, elongate scales on the elevated midrib and broad scales on the blade of the leaf of *Photinia arbutifolia*; *B*, scales of various shapes and sizes from several host plants; *C*, *D*, and *E*, scales on *Fatsia* (*Aralia*) *japonica*, *Asparagus Sprengeri*, and *Cedrus Deodara*, respectively.

MORPHOLOGICAL CONFORMATION TO HOST PLANTS

The shape of the nigra scale is profoundly influenced by the species of host plant and by the form of the plant structure on which the scale develops. Two strikingly different shapes are shown on the lower side of a leaf of *Photinia arbutifolia* in figure 15, *A*. Scales that develop on narrow leaves like those of asparagus fern and deodar cedar (fig. 15, *D* and *E*) are notably slender and subcylindrical, while scales on the leaves of aralia (fig. 15, *C*) and ivy (fig. 17) are broad and flat. Scales on the slender branchlets of *Callistemon viminalis*, *Leptospermum laevigatum*, and *Pittosporum phillyraeoides* are more slender and taller than those that develop on the narrow leaves. Scales that develop on the branchlets of *Schinus Molle*, *S. terebinthifolius*, *Rhus integrifolia*, and *Arctostaphylos manzanita* are elongate and decidedly convex. Scales that develop on the bark of *Euonymus* sp. and *Carissa grandiflora* are typically long-oval and convex. The broad-oval form, "sometimes one side nearly

straight, or incurved," as described in the earlier writings, is the typical form occurring on broad leaves, such as those of *Hedera* spp., *Euonymus japonicus*, *Nerium Oleander*, *Ilex* spp., *Pittosporum undulatum*, and *Fatsia* (*Aralia*) *japonica*. The scale that develops along a vein or the midrib of a leaf is likely to have one side of the body straight. Sometimes, however, one side may be nearly straight, or incurved, and the front may be narrowed or extended, even where the scale is not adjacent to a vein or midrib.

NATURE OF INJURY TO HOST PLANT, AND ECONOMIC IMPORTANCE

Injury to the plant is caused by the feeding of the scale and by the excretion of honeydew upon the leaves. The feeding results in three types of injury: (1) mechanical injury resulting from the insertion of the rostralis into the tissues, (2) toxic effects due to injection of saliva into the tissues in the process of feeding, and (3) devitalization of the plant caused by the removal of sap or other constituents in liquid form. As compared with sucking insects in general, the nigra scale is not obviously injurious. So far as has been observed in the present investigation, the scale causes no deformation of the infested parts and no necrosis of the tissue in which the rostralis operates. Infested plants or parts of plants exhibit a retardation in growth and an accentuated aging and shedding of leaves, but these effects are not particularly evident to the casual observer. Plants that are properly watered may be infested moderately heavily for a period of 6 or 8 months, without appreciable defoliation. Individual leaves on plants of *Hedera Helix*, *Nerium Oleander*, *Pittosporum undulatum*, and *Ilex Aquifolium* were tagged experimentally and observed to be infested rather heavily for two consecutive years. Adjacent leaves were brushed frequently to keep them free of scales. The infested leaves of the first three dropped about 3 months before the uninfested leaves, but the infested leaves of *I. aquifolium* remained on the plant and showed no effect from the scale. The heaviest shedding occurred to infested foliage of the interior, shaded parts of plants.

Killing of branches has been observed where the bark has been heavily infested on plants growing in poor soil and under deficient conditions of moisture. This form of injury has been observed particularly on *Rhus integrifolia* growing in the chaparral on the southwest slopes of the Santa Monica Mountains, and on cultivated shrubs growing under nonirrigated conditions in parks on the west side of San Francisco Bay.

Honeydew is produced chiefly during the period of the insect's rapid growth, from March to May, and during the period of egg laying, from June to November or December. The honeydew on the leaves forms a sticky deposit which collects dirt and promotes the growth of sooty fungus. Leaves coated with honeydew and sooty-mold fungus are probably weakened to some extent, as a result of the impairment of photosynthesis.

Many references to the injurious effects of the nigra scale are found in the literature. Green (1896) states that in the earlier days of coffee growing in Ceylon, the nigra scale was but a little less destructive than *Lecanium viridis* Green, which caused much havoc to coffee plantations. Cockerell (1894) states that infestations on Ceará rubber trees produce a heavy fall of leaf. South

(1913) states that heavy infestations on cotton cause the plants to dry up and look as though they had been blasted. A malady of the sandal plant, known as spike disease or stag-headedness, in India, has been associated with the nigra scale (Anon., 1931). Continuous feeding of the scale for 5 months is reported to have caused dieback of branches and stag-headedness of the sandal plant.

Importance as a Pest of Ornamental Plants.—Since ornamental shrubs and trees are commonly given scanty watering during the dry season, the accentuated defoliation resulting from infestation by nigra scale causes them to appear unsightly. Unsightliness also results from the growth of sooty-mold fungus and from the dirt that adheres to the honeydew-coated foliage. Garden flowers, lawn grass, and other plants growing near infested shrubs and trees become unsightly as a result of the honeydew cast off by the scales, and the dirt shed from the infested leaves. The walls of buildings adjacent to infested plants, sidewalks, and anything left under infested trees during the spring and summer months may become unsightly. Clothes are soiled by contact with the plants.

For the three or four years before 1940, the nigra scale surpassed all other lecanine scales in prevalence and abundance on ornamental shrubs and trees in the coastal region of the state, where a large part of the nursery stock is grown. Since nurserymen are obliged to have their stock of plants free of pests, much time and money are expended in keeping the numerous host plants free from the scale.

Importance as a Pest of Agricultural Crops.—The nigra scale is a pest of minor importance to a large number of agricultural plants. In various tropical and semitropical parts of the world, it has at times been an important pest of coffee trees, rubber trees, croton-oil plants, cotton, sandal trees, cherimoya, guava, mango, and papaya. Though in 1862 Nietner regarded it to be of "no importance" to coffee planters, Green (Nietner, 1880)[15] later stated that in 1847 the scale had "caused general alarm among planters," and that it "is capricious in its habits, here attacking a single tree, there an entire estate." The history of the scale after the year 1880 shows that coffee trees have been attacked in the East Indies, Ceylon, India, East Africa, the West Indies, South America, and Central America; but as far as can be ascertained from the literature, prolonged infestation and serious damage have been averted as a result of the work of natural enemies.

The scale has been reported to be a pest of cotton in the West Indies, British Guiana, Equador, Hawaii, Formosa, China, India, and Africa. Ritchie (1916) stated that in Jamaica the nigra scale was abundant wherever cotton was grown, and that insecticidal control was necessary. Wolcott (1933) reported that the nigra scale was formerly considered a major pest of cotton in the West Indies, but that more recently its status had been reduced to that of a minor pest as a result of improved cultural practices and the work of natural enemies. Rubber trees of the genera *Ficus* and *Hevea*, and *Manihot Glaziovii* (Ceará rubber) have been reported in many regions as heavily attacked. In Ceylon in 1936, *Saissetia nigra* was said to be the scale most commonly attack-

[15] The statement in the reference cited is attributed to Green rather than to Nietner because it did not appear in the original treatise by Nietner, published in 1861.

TABLE 4

Agricultural Plants Attacked by the Nigra Scale

Name of plant	Susceptibility to infestation	Place where recorded as a host
Fruits and nuts:		
Almond (*Amygdalus communis*, or *Prunus Communis*)	Low	California, West Indies
Avocado (*Persea americana*)	Low	Africa, California, West Indies
Banana (*Musa* sp.)	High	Hawaii, Central America, South America, West Indies
Cherimoya (*Annona cherimola*)	High	Australia, Ceylon, West Indies
Citrus:		
Citrus sp.	Low	Bermuda, Egypt, Formosa, Queensland, Mozambique, New South Wales, South Africa
Eremocitrus sp.	Low	Australia, Queensland
Grapefruit (*Citrus paradisi*)	Low	California
Lemon (*Citrus Limonia*)	Low	California
Lime (*Citrus aurantifolia*)	Low	Bermuda
Orange (*Citrus sinensis*)	Low	California, Queensland
Coconut (*Cocos nucifera*)	Medium	Hawaii, India
Feijoa, pineapple guava (*Feijoa Sellowiana*)	Medium	California
Fig (*Ficus Carica*)	Low	California, Egypt, Formosa, South Africa, West Indies
Grape (*Vitis vinifera*)	Low	Egypt, Australia
Guava (*Psidium* sp.)	High	Australia, California, Formosa, Hawaii, West Indies
Loquat (*Eriobotrya japonica*)	Low	California
Litchi (*Litchi chinensis*)	Low	California
Mango (*Mangifera indica*)	Medium	California, Florida, Hawaii, South Africa
Olive (*Olea europaea*)	Low	California
Papaya (*Carica Papaya*)	Medium	Florida, Queensland, West Indies
Passion-flower (*Passiflora* sp.)	Low	California
Peach (*Prunus Persica*)	Low	California
Pepino (*Solanum muricatum*)	Low	California
Pineapple (*Ananas sativus*)	Low	Hawaii
Pistachio nut (*Pistacia* sp.)	Low	California
Plum (*Prunus domestica*)	Low	California
Queensland nut (*Macadamia ternifolia*)	Low	California
Sapote (*Lucuma mammosa*)	High	California
Sapote, white (*Casimiroa edulis*)	High	California
Sapote, woolly leaf white (*Casimiroa tetrameria*)	High	California
Soursop (*Annona muricata*)	High	Uganda
Sweetsop (*Annona squamosa*)	High	West Indies
Agricultural plants other than fruits and nuts:		
Cassava (*Manihot esculenta*, or *M. utilissima*)	Medium	Ceylon, India, Malaya
Cinchona, medicinal (*Cinchona officinalis*)	Medium	Ceylon, South America
Cinchona, redbark (*Cinchona succirubra*)	Low	Ceylon, South America
Castor-oil plant (*Ricinus communis*)	Low	Ceylon, India, Seychelles
Coffee (*Coffea* sp.)	Medium	Africa, Ceylon, East Indies, India, Malaya, Central America, South America
Cotton (*Gossypium* sp.)	High	Africa, Ceylon, China, Formosa, Hawaii, India, Japan, West Indies, South America, South Sea islands
Croton-oil plant (*Croton Tiglium*)	High	Ceylon, Hawaii, India, Malaya, South America
Silk-cotton tree, kapok (*Ceiba pentandra*)	Medium	Java, Malaya
Pará rubber tree (*Hevea brasiliensis*)	High	Ceylon, East Indies, India, Malaya, South America
Ceará rubber (*Manihot Glaziovii*)	High	Africa, Ceylon, India, South America, West Indies
Native rubber tree (*Sapium Jenmanii*)	Medium	South America
Sandalwood (*Santalum* sp.)	High	India
Teak tree (*Tectona grandis*)	Medium	East Indies, West Indies

ing various species of *Annona* (cherimoya), and to be periodically controlled by parasites (Anon., 1936).

The agricultural plants on which the scale has been reported include 32 species of fruits and nuts, and 14 other species of plants. The names of these plants, the regions where the scale has been reported on the various plants, and the degree of susceptibility to attack are presented in table 4. The degree of susceptibility to attack, indicated in the table is, in many instances, based on inadequate evidence or information. Many writers have mentioned that infestations are frequently capricious in degree and extent. Presumably, the variability in infestations is related to the activity of natural enemies.

Importance as a Potential Pest of Citrus in California.—The great increase of the nigra scale in recent years has given rise to the apprehension that the insect might become an important pest of citrus in California.

Citrus is apparently more commonly attacked in Australia than in California. Tryon (1917) stated that citrus was attacked by this scale in several localities in Queensland. Flanders found the nigra scale in small numbers on orange at Goondiwindi, Queensland, in 1931.[16] Hall and Ford (1933) merely included it among Rhodesian citrus insects "which are known to be harmful or strongly suspected of causing injury." Coutinho (1931) stated that it was a little more abundant than soft (brown) scale on citrus in the Lourenco Marques district of Mozambique. Ogilvie (1928) merely stated that the nigra scale was one of several scales found on citrus, especially lime trees, in Bermuda. It was reported by Takahashi (1929) on various species of citrus in Formosa. Sasscer and Weiger (1923) reported it on citrus in the propagating house of the United States Botanic Gardens at Washington, D. C. Various additional published references to the nigra scale on citrus have been found to be errors due to the misinterpretation of the common name "black scale," the species actually concerned being *Saissetia oleae.*

In California the nigra scale has been reported at various times on citrus trees in the western part of Los Angeles County by inspectors of the County Agricultural Commissioner's office. In the course of the present investigation, the writer has seen infestations on citrus on five different properties in the western part of the city of Los Angeles, as follows: (1) a light infestation in a 20-acre lemon grove, (2) a light infestation on 8 lemon trees in an abandoned grove, (3) an infested grapefruit tree, (4) a lightly infested orange tree, and (5) a rather heavily infested orange tree. The infestation in the 20-acre lemon grove was first reported in 1938 by Kenneth Smoyer, the agricultural inspector in the West Los Angeles district. The scales occurred in small numbers on many trees in the grove. The infested trees were adjacent to heavily infested chaparral growth of *Rhus integrifolia.* The infestation in the grove was eradicated by fumigation with hydrogen cyanide at the dosage commonly used on citrus. On the 8 lemon trees in the abandoned grove, the scale was found scatteringly, in small numbers, on all the trees. These trees were adjacent to chaparral in which there were heavily infested shrubs of *R. integrifolia.* The infested grapefruit tree was in a dooryard and had a much larger number of scales than was observed in any of the lemon trees mentioned above; one branch was rather heavily infested. The two infested orange trees were in

[16] Flanders, S. E., in letter to the author, September 22, 1939.

dooryards. On the heavily infested tree the scales occurred on the leaves (fig. 16), the green bark (fig. 16), and the fruit.

The two rather heavy infestations that have been found here tend to indicate that citrus is susceptible to serious attack. The danger that the scale may become an important pest of citrus lies principally in the possibility that a host-specific form may develop. Thus far, however, citrus must be regarded as a casual host. The infestations reported were the only ones found, notwithstanding the fact that frequent inspections were made of a large number of citrus trees in areas where the scale was abundant on other hosts.

Fig. 16.—Nigra scale on the leaves and green bark of an orange tree, taken in the western part of Los Angeles County.

SEASONAL HISTORY OF THE NIGRA SCALE

In California the nigra scale has but one generation a year. The adult stage is reached in April, May, or June. The beginning of this stage can be recognized by the development of the black color on the back of the scale and by the beginning of egg laying. Egg laying takes place continuously from about the middle of May to February of the following year, a period of 9 or 10 months. The greater percentage of the eggs are laid during the months of May, June, July, August, and September. The eggs hatch in from 1 to 3 weeks, the length of the incubation period being shorter in the summer than in the fall and winter.

Very little growth takes place during the summer, fall, and early winter months. The insects that hatch in December and January apparently reach the adult stage about the same time as those that hatch the preceding May. The period of growth is principally February, March, and April. The second ecdysis takes place mainly in February and the first half of March, but a small percentage of the scales effect it in November, December, and January. This fact can be determined by the examination of living specimens under the microscope: the second-instar scales (fig. 7, *A*) have approximately 72 fringe setae and no dorsal setae, whereas the third-instar scales (fig. 8, *A*) have approximately 120 fringe setae and many dorsal setae. Prior to the second ecdysis, the scale appears translucent greenish or translucent yellowish, the

Fig. 17.—Adult nigra scales (136 in number) and, first- and second-instar scales (3,625 in number) on the lower side of an ivy leaf. Photographed September 4, 1939.

Fig. 18.—Third-instar scales in the whitish stage, at the beginning of the period of rapid growth, on leaves of *Pittosporum* and ivy. Photographed April 2, 1940.

green color caused by the fact that the leaf shows through the translucent body of the scale. After the second ecdysis, the scale gradually turns whitish. During April and May the color changes to reddish brown and then to jet-black. The seasonal development is illustrated in figures 17 and 18. The adults shown on the ivy leaf in figure 17 began laying eggs in May and all were laying eggs when the photograph was taken on September 4. The photographs in figure 18 were taken April 2, 1940, and show third-instar scales in the white condition, during the period of rapid growth. It will be noted that the scales are uniformly the same size.

A small number of off-hatch or off-season scales have been observed. Near the coast in Santa Cruz County a few preadult, whitish individuals were found in September, 1939, and many in that stage were found the middle of June, 1940. In southern California, off-hatch individuals have been found occasionally on heavily shaded plants growing in cool locations. The off-hatch condition has been found less frequently than some facts would seem to indicate. In March one may sometimes find scales ranging in development from first instar to third instar, whitish stage, and even the reddish-brown stage. Theoretically, those in the first instar would be expected to reach the adult stage much later than would the main population. The rate of growth and development of the more immature individuals seems to be so greatly accentuated in the late winter and early spring months, however, that the entire population reaches the adult condition at about the same time. This peculiarity in seasonal development deserves further study.

The length of life of the adult scale appears to be related to the length of the preadult period of development. This point has not been demonstrated experimentally but is supported by certain facts, some of which may be mentioned. Where host plants are situated in habitats of high temperature and much sunlight, the length of life is relatively short. In such habitats all individuals attain the adult, egg-laying stage in April, May, or early June, and die that same summer or early fall. No living adults are to be found during late fall and winter. On the other hand, where host plants are situated in shaded, cool habitats, the length of life of the insect is greater and there is a prolongation of seasonal development; but the adult condition is reached in April, May, or June, at about the same time as that of populations in habitats of high temperature. Some adults in such habitats begin laying eggs at a rapid rate and die in midsummer. These are probably individuals that hatched the preceding June. At the other extreme are individuals that, upon attaining the adult condition, begin laying eggs at a very slow rate and continue through the fall and winter. These are probably individuals that hatched the preceding fall and winter.

A large percentage of the insects apparently remain in a fixed position from the time the crawler settles until the death of the adult. Movement from one point to another may take place, however, any time during a period of 8 or 9 months from the time of settling until the preadult, reddish-brown stage. A considerable amount of migration takes place after the second ecdysis. At that time there is a pronounced tendency for the insects to move from the blade of the leaf to a position along the midrib or, in the case of host plants having thin leaves, to move from the leaves to the bark.

LIFE HISTORY

Like other lecanine scale insects, the female nigra scale has two ecdyses and three instars of development. In the life history of this scale, seven stages of development are clearly distinguishable: (1) the egg, (2) the crawler, (3) the settled stage of the first instar, (4) the second instar, (5) the preoviposition stage of the third instar, (6) the oviposition stage of the third instar, and (7) the postoviposition stage. These seven stages are illustrated in figure 19.

Egg Stage.—As many as 300 unhatched eggs are sometimes found under an adult scale. In such instances the first eggs laid are from 10 to 20 days older than the last ones. The age is roughly indicated by certain changes that take place as the embryo develops within the thin transparent shell. As embryonic

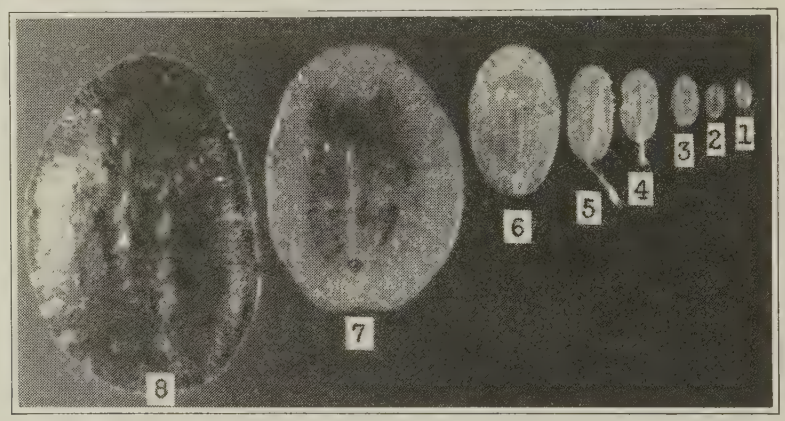

Fig. 19.—Nigra scales in various stages of development: 1, egg; 2, crawler; 3, first-instar, settled stage; 4, second instar immediately after the first ecdysis, with the shed skin of the first instar attached to the end of the body; 5, third instar immediately after the second ecdysis, with the shed skin of the second instar attached; 6, third instar at the beginning of the period of rapid growth, in March or April; 7, preadult, reddish stage; 8, adult. The specimens shown in this photograph were collected in a cool, well-shaded habitat where the scale occurred in all stages of development.

development proceeds, orange pigment becomes apparent and two dark eyespots develop. For a period before emergence, the body segments, the antennae, and the legs can be seen faintly through the eggshell. The duration of the egg stage ranges from about 5 days in warm summer weather to a month or more in fall and winter. Emergence usually requires about a half hour. The anterior end of the eggshell is ruptured as a result of pressure exerted by movements of the insect's body. Continued movements cause the eggshell to pass backward and collapse toward the posterior end of the body, as indicated in figure 3, *B* (p. 238).

Crawler Stage.—After freeing itself from the eggshell, the infant insect, known as a crawler, may remain for a period of hours, or even days, under the body of the parent female. Newly hatched scales have lived in confinement, without food and at a mean temperature of 74° F, for a period of 4 days. Once free upon a leaf, the crawler moves actively but, as far as can be per-

ceived, without purpose. Obviously, the crawler must possess some instinct which, under a particular stimulus, causes it to stop and force its rostralis into the plant tissue and start feeding. Just what the particular stimulus is, no one can say. The writer has studied the movements and behavior of scores of crawlers. Some individuals have been observed to settle within a few minutes after obtaining freedom from the egg, some have settled after hours of crawling, but a large majority have perished from exhaustion or starvation without settling. Under varying natural conditions, there is probably a wide range in the percentage of crawlers that perish. Studies made in 1937–38 indicated that over 90 per cent of the crawlers died without settling.

Settled Stage of the First Instar.—The insertion of the rostralis into the plant tissue marks the beginning of the settled stage. In the initial process of settling, slight movements of the body can be observed. After a few days the body becomes very closely pressed to the leaf or bark. In summer the duration of the first-instar settled stage ranges from 2 to 3 weeks. The end of the stage is marked by the first ecdysis. In the process of ecdysis, the skin splits at the anterior end of the body and at the same time loosens all over the body. It is worked backward off the body, but the insect does not change its position during the process. The molted skin may remain for days attached to the end of the body, as shown in figure 19. The rostralis is shed but remains in the plant.

Second Instar.—The rostralis of the second-instar stage is apparently inserted into the plant before the first-instar skin is shed, and the scale is held to the plant by the rostralis during the process of ecdysis. The second-instar scale has legs, antennae, and eyes, and is capable of moving about, but may remain in a fixed position throughout the period. With scales that hatch in late spring and summer, growth and development during this stage are extremely slow. The stage lasts from 2 to 6 months. The end of the instar is marked by the second ecdysis.

Preoviposition Stage of the Third Instar.—The second ecdysis is like the first, the rostralis of the next instar being inserted into the plant before the skin of the preceding instar is shed. Sometimes the scale becomes more or less opaque before the second ecdysis. The preoviposition stage covers a period of 1 or 2 months and is the stage of marked growth. The scale rapidly increases in all dimensions, to the adult size, and the body becomes filled with ovarian organs. The color changes from whitish to reddish, from reddish to brown, and from brown to black. The ventral part of the body of individual scales varies from colorless to decided salmon or rose. The body becomes so large in proportion to the legs, that the insect no longer has the power to move. Small patches of wax, regularly spaced, form around the edge of the body, and less regularly spaced over the top of the body. Before egg laying begins, the posterior ventral portion of the body becomes covered by a powdery white wax. This substance continues to be given off during egg laying, particularly during the first few weeks.

Oviposition Stage of the Third Instar.—At first the rate of egg laying is slow, but later the rate varies greatly among different scales. Some may lay 3 or 4 eggs a day for a period of a month or two, increase to a rate of 10 or 15 a day until a total of 600 or 800 eggs have been laid, then decrease gradually,

As egg laying proceeds, the ventral portion of the abdomen contracts, and a concavity is formed in which the eggs and eggshells accumulate. The body substance of the scale slowly becomes transformed to eggs. Some individuals continue to lay until the organs and membranes are scarcely more than a thin lining covering the lower side of the hard dorsal wall of the body. The oviposition stage varies in length from 2 or 3 months to 8 or 10 months. The shorter period applies to scales on plants in situations of high summer temperature, the longer to those on plants in shaded, cool situations.

Postoviposition Stage.—The scale dies by degrees, so to speak, as the body tissues become transformed to eggs. Actual death does not occur, however, until days or weeks after egg laying ceases. This fact can be determined defi-

TABLE 5

NUMBER OF CRAWLERS, EGGS, AND EGGSHELLS FOUND UNDER ADULT NIGRA SCALES DURING THE EGG-LAYING PERIOD, 1940

Date, 1940	Adult scales examined	Crawlers		Eggs		Eggshells		Eggs and eggshells	
		Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average
July 25	10	64	33	286	132	839	448	1,189	613
August 29	10	69	25	207	95	1,425	789	1,632	884
September 30	10	18	4	26	10	744	439	751	449
November 5	10	13	3	26	8	548	445	552	453
December 10	10	26	6	91	26	975	713	980	739
Average	..	..	..	...	..	...	...	1,021	628

nitely by simply overturning old scales. If unhatched eggs are present and if some of them are pale-translucent, as is characteristic of newly laid eggs, the scale is still ovipositing. If no unhatched eggs are present and the remaining body tissues are soft and contain more or less liquid, the scale is alive but may have entered the postoviposition stage. If no eggs are laid for a few days while the scale is on its back, one may safely conclude that the scale is in the postoviposition stage. If the body tissues have dried up, or if the tissues have nearly dried up and no movement of the legs can be detected, one may conclude that the scale is dead. Green (Cotes, 1889) stated that the eggs do not hatch until after the death of the parent insect. This satement is believed by the present writer to have been based upon erroneous observations, for it seems very improbable that this feature of the biology of the scale in Ceylon, where Green made his report, is notably different from that in other parts of the world.

FECUNDITY

To ascertain the reproductive capacity of the nigra scale, counts were made of the number of crawlers, unhatched eggs, and eggshells found under adult scales at intervals during the main egg-laying period, from July 25 to December 10, 1940. Ten adult scales of average size were selected for determining the average number of crawlers, eggs, and eggshells at the time of each examination. The data are presented in table 5. The reproductive capacity is indicated by the combined number of eggs and eggshells. The count made on August 29 (table 5) showed an average of 884 eggs and eggshells per scale,

the highest average obtained during the period. The average for the entire period was 628 eggs and eggshells per scale. The largest number found under a single scale was 1,632 on August 29. The smallest number of eggs and eggshells per scale was obtained in the count on November 5, the average being 453.

When the counts were made on August 29, 1940, 7 additional, large-sized adults were selected, and the eggs and eggshells were counted. The average number per scale was 1,234 and the largest number for any one scale was 1,812.

PARTHENOGENESIS

During the present study, no male specimens of the nigra scale were found, though a persistent search for males was made. The writer believes that males do not occur in California and that the females reproduce wholly by parthenogenesis. Atkinson (1887) and Green (Cotes, 1889; Green, 1904) described the male of *Saissetia nigra,* but no other writers have recorded its existence. Atkinson's reference to the male is contained in a single sentence, quoted as follows: "Male scarcely differs from that of [*Lecanium*] *coffeae,* the head and thorax are not so bright in colour, but the wings appear more strongly hyaline." Green (1904) describes and illustrates the male larva, puparium, and adult. Since Atkinson's description of the female scale is practically a word-for-word quotation of the original description by Nietner (1861), there is reason to believe that his reference to the male was based not on his own observation but rather on statements made by Green in an article said by Cotes (1889) to have been published first in 1886 and republished, in part, by Cotes in 1889. Green's description and illustrations of the male, published in 1904, may have been based entirely upon the observation reported in 1886. At any rate, the illustrations appear to be substantially the same. In view of these considerations one may question whether the male described by Green was, in fact, *Saissetia nigra.*

NATURAL MORTALITY

The term *natural mortality* is here considered to mean the dying of scales prematurely as a result of environmental resistance, host resistance, and factors other than parasites and predators. It involves the postulation that the scale may be subject to fungus, bacterial, and virus diseases not yet known to science. In these particulars the nigra scale is probably not different from many other species of lecanine scales.

Natural Mortality of Eggs.—Occasionally during the fall and winter, large numbers of eggs are killed, apparently by pathogenic organisms. This condition is revealed when living adult scales are overturned and all the eggs underneath are found to be purplish or brownish, and nonviable. There are several reasons for believing that pathogenic organisms are involved: (1) the adult scale appears to be normal; (2) large numbers of eggshells invariably present show that for weeks, or perhaps months, the eggs produced were unaffected; (3) the accumulation of dead eggs suggests that a pathogen, once established under a scale, infects the eggs as soon as they are laid. The occurrence of dead eggs in the fall and winter months may be related to the fact that rains would tend to disseminate the pathogen. On the other hand, the pathogenic organism may perhaps be transmitted through the egg.

Natural Mortality of Crawlers.—The highest natural mortality occurs in the crawler stage. For some undetermined cause, only a small percentage of the crawlers attain the settled stage. In studies made in the laboratory and outdoors, crawlers were released on the leaves of *Pittosporum undulatum,* and their behavior was observed in detail. There seems to be no way to explain why perhaps one crawler out of 100 settled and the other 99 perished from exhaustion or starvation or fell from the leaf without settling. Studies made from July 20, 1937, to March, 1938, indicated that well over 90 per cent of the crawlers failed to become established. The mortality was confined almost wholly to crawlers that had left the shelter of the parent scale. During the fall and winter, a small number of dead crawlers may be found under the parent scales. Death in such instances may be due to pathogenic organisms, but in most instances it is probably due to the fact that the crawlers become imprisoned by the accumulation of eggshells.

Natural Mortality of Settled Young Scales.—Usually a large percentage of scales die during the settled stage of the first instar and during the early part of the second instar. Studies made in 1938–1940 indicated that on some plants as high as 80 per cent of young scales died from causes other than parasites and predators, even though conditions were apparently favorable for development. In such instances the scales appeared to become sick, as though affected by a slowly lethal disease. The first indication of impaired health was the development of a faintly brownish color, which gradually became darker. After death the body dried up and remained attached to the leaf for weeks or months.

Mortality Associated with Winter Migration.—During the period from January to March, there is a pronounced shifting about of the scales, particularly on heavily infested leaves. In this activity the scales move from places where they originally settled to places where they are less crowded. On some host plants, such as *Schinus terebinthifolius* (Brazilian pepper tree), and *Rhus integrifolia,* there is a marked migration of the scales from the leaves to the bark of the twigs and branches. In the course of this relocating, a large percentage of the scales fall from the plant or otherwise fail to reëstablish themselves. The percentage of scales lost during migration has been found to vary considerably in differing locations and in different years.

As previously stated, the second ecdysis takes place principally during the months of January, February, and March. This metamorphic change may render the scales vulnerable to attack by pathogenic organisms and may account for the fact that sometimes large numbers of scales turn brown and die during these months. In March, 1940, soon after the migration period, a remarkably high natural mortality was observed. In some places the scale apparently became totally exterminated. The scales became slightly cream-colored or faintly brownish and soon dropped from the host plants. Shrubs that were heavily infested became completely depopulated within a period of 3 weeks.

Symbiotic Organisms in Relation to Natural Mortality.—While investigating the possibility that the mortality of the nigra scale was caused by a pathogenic organism, Clark Evernham, a student at the University of California at Los Angeles, discovered, in 1940, that the body of the scale is nor-

mally inhabited by a yeastlike organism. This organism, identified as a species of *Torulopsis* or *Rhodturla,* occurs in large numbers throughout the body of the scale. Without doubt it is essentially symbiotic in nature and is similar to other symbionts long known to inhabit the bodies of scale insects.[17] There is a possibility that under certain conditions the symbiont may become parasitic and bring about the death of the scale. The symbiont is evidently transmitted from generation to generation through the egg, for it is found in all stages of the scale. It appears to occur in largest numbers in third-instar larvae and in adult scales.

PREDACEOUS ENEMIES OF THE NIGRA SCALE

Seven species of insects are mentioned in published records as predaceous on the nigra scale, and Wolcott (1933) states that in the West Indies the scale is eaten by birds and lizards. The predaceous insects include three species of Diptera belonging to the family Cecidomyidae, three species of Lepidoptera, and one species of coccinellid beetle. In the present investigation in California, numerous species of predators were found. These were distributed among the orders Diptera, Lepidoptera, Coleoptera, Neuroptera, Hemiptera, Thysanoptera, and Acarina.

Dipterous Predators.—Rutherford (1914) states that in Ceylon the eggs of the nigra were fed upon by a cecidomyid larva, unidentified as to species. Felt (1915) describes *Xiphodiplosis fulva* Felt and states that the specimens had been reared from the nigra scale on dahlia in Ceylon. In a later paper, Felt (1921) records *Diadiplosis cocci* Felt as a predator on nigra-scale eggs in the West Indies.

In California the larvae of two or more species of Syrphidae were observed occasionally to feed upon first- and second-instar nigra scales.

Lepidopterous Predators.—Bodkin (1917) states that in British Guiana the nigra scale and three other species of lecanine scales were attacked by larvae of three species of moths, *Blastobasis lecaniella* Busck, *Vitula bodkini* Dyar, *Vitula toboga* Dyar. Several larvae of an undetermined species of moth were found by the present writer underneath adult nigra scales killed with cyanide and sent from Puerto Rico in 1940.

Coleopterous Predators.—The only published record of coleopterous predators is by Urich (1916), who states that in Trinidad the coccinellid *Azya orbigera* Muls. preys upon the nigra scale. In 1940 Flanders took 50 specimens of *Scymnus flavifrons* (Melch.) in a shipment of the scale from Puerto Rico.[18]

The species of Coccinellidae observed to attack the nigra scale in California are *Chilocorus bivulnerus* Muls., *Cycloneda munda* (Say), *Olla abdominalis* (Say), *Adalia bipunctata* (Linn.), *Rhizobius ventralis* (Er.), *Lindorus lophanthae* (Blaisd.), and one or more species of *Scymnus*. The first four species named and the *Scymnus* sp. were observed to be casual predators under conditions of heavy infestation. The beetles and their larvae fed upon first- and second-instar scales. *R. ventralis* and *L. lophanthae* are prevalent enemies of the nigra scale, even under conditions of light infestation.

[17] The subject of internal symbionts of insects has been reviewed by Steinhaus (1940). Important contributions pertaining to symbionts of scale insects have been made by Brain (1923), Schrader (1923), Granovsky (1929), and Couch (1938).

[18] Flanders, S. E., in letter to the author, August 31, 1940.

Rhizobius ventralis has long been known as a predator of lecanine scales in California. The female beetle deposits an egg, or sometimes several eggs, under an adult scale. Where two or more larvae hatch under a scale, cannibalism takes place and but one survives. The larva feeds upon the eggs of the scale. If the beetle deposits an egg under a scale that has not begun to oviposit or if all the eggs beneath the scale have been consumed, the newly hatched larva may either attack the adult scale (fig. 20, *A*) or crawl from under the scale and live freely on the surface of the plant, feeding upon the young scales. On plants heavily infested by young scales, the beetle also deposits some eggs on the leaves, and the larvae feed directly on the young scales. The smaller

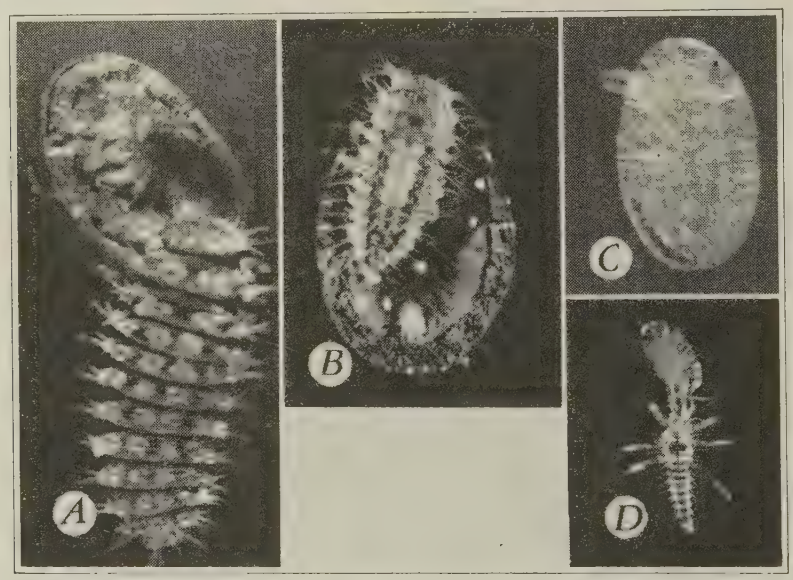

Fig. 20.—Photomicrographs of predaceous enemies feeding on the nigra scale: *A*, larva of *Rhizobius ventralis* (Er.), and *B*, larva of *Lindorus lophanthae* (Blaisd.) feeding on an upturned adult nigra scale; *C*, predaceous mite (*Syncaligus* sp.) feeding on the left side of a first-instar nigra scale; *D*, first-instar larva of *Chrysopa californica* (Coq.), feeding on a young nigra scale.

free-living larvae do not consume the young scales, but merely suck out the body contents and leave the crumpled body of the scale hanging by the rostralis to the plant. Free-living larvae are voracious feeders. One nearly full-grown larva consumed 1,200 early second-instar nigra scales in 3 days. The full-grown larva is 5 mm long and dull black, sometimes with 6 rows of grayish areas on the dorsum of abdominal segments 1 to 8. The adult beetle feeds upon the young scales. The beetle is black, nearly circular in outline, and about 3 mm long and nearly 3 mm wide.

Lindorus lophanthae has long been known as a predator of diaspid and lecanine scales in California. As an enemy of the nigra scale, it has been considerably less important than *Rhizobius ventralis*. In life history and habits, the two species are very similar. The full-grown larva (fig. 20, *B*) of *L. lophanthae* is 3.5 to 4.0 mm long. The larva has a prominent quadrangular whitish

area on the dorsum of abdominal segments 1 to 4; the remainder of the body is dark. There are two pairs of pale, short bristles on the dorsum of abdominal segments 1 to 4, and one pair on segments 5, 6, and 7. Two prominent tubercles bearing long white hairs occur on either side of the mesothorax, the metathorax, and each of the abdominal segments. The adult beetle deposits an egg, or sometimes 2 or 3 eggs, under an adult scale. The larva feeds upon the eggs of the scale. If all the eggs are consumed, the larva may attack the adult scale, but usually it crawls from under the adult and feeds freely upon the young scales. The beetle is about 2.5 mm long and 2.0 mm. wide and is nearly circular

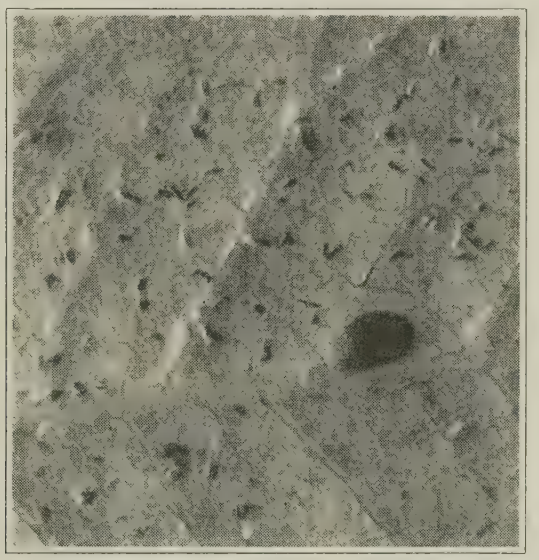

Fig. 21.—Section of leaf bearing an adult nigra scale and the crumpled bodies of dozens of young scales killed by larvae of *Chrysopa californica* (Coq.), and by young larvae of *Rhizobius ventralis* (Er.) and *Lindorus lophanthae* (Blaisd.).

in outline. The pronotum is reddish; the elytra are black and covered by fine hairs. The life cycle of several individuals averaged 24 days from the time the egg was laid until the adult beetle emerged.

Neuropterous Predators.—During the years 1937 to 1939, when the nigra scale was exceedingly abundant in many districts, the California green lacewing, *Chrysopa californica* (Coq.), and the Pacific brown lacewing, *Hemerobius pacificus* Banks, were important predators. In a few instances, larvae of Hagen's dusty wing, *Conwentzia hageni* Banks, were observed to feed upon crawlers and first- and early second-instar scales.

Chrysopa californica is a well-known predator of aphids and various other soft-bodied insects in California but apparently has not heretofore been recorded as an important enemy of scale insects. During the peak of the nigra-scale infestation in the summer of 1939, hundreds of *Chrysopa* eggs were commonly observed on infested shrubs. The larva is remarkably voracious and moves actively over infested leaves, searching out young scales with the aid

of its long forceplike sucking jaws. The body content of the scale is quickly sucked out, and the crumpled body is left hanging by the rostralis. Most of the crumpled scales shown in figure 21 were killed by larvae of *C. californica*, but some were killed by young larvae of the beetles *Rhizobius ventralis* and *Lindorus lophanthae*. In figure 20, *D*, a first-instar larva of *C. californica* is shown in the act of feeding upon a second-instar nigra scale.

Hemerobius pacificus is less prevalent than *Chrysopa californica* as a predator of the nigra scale. But some infestations of first- and second-instar scales have been almost exterminated by this predator. If all the young scales have been killed, the larva may attack the adult scales. The long sucking jaws are thrust under the edge of the scale, and often the scale is lifted or tilted during the feeding of the larva. The eggs are laid at random on infested parts of a plant. In habits and general appearance the larva resembles that of *C. californica*.

Hemipterous Predators.—In the course of the study of the nigra scale, predaceous bugs were rarely found to attack the young scales. In no instance were they numerous, and they must be regarded as unimportant enemies of the scale.

Thysanopterous Predators.—The black hunter thrips, *Leptothrips mali* (Fitch), was observed in a few instances to prey upon young nigra scales.

Predaceous Mites.—The role of predaceous mites as enemies of the nigra scale has been given only minor consideration. Special problems are encountered in identifying and determining definitely the habits of the many species found on scale-infested plants. Some species appear to be scavengers that feed on the bodies of dead scales. Often mites were observed to feed on young scales that appeared to be in a devitalized or dying condition, and occasionally mites were observed to attack apparently normal, live young scales. All such mites were free-living rather than parasitic. After feeding on a scale for a few minutes, without apparent harm to the scale, the mite would scurry away. In figure 20, *C*, a mite, *Syncaligus* sp., is shown feeding on a first-instar nigra scale. The injury caused by the momentary attacks of such mites may possibly account for the ultimate death of large numbers of scales. Parasitic mites are often found attached to the underside of alult scales, but rarely do they occur in large enough numbers to be regarded as capable of greatly weakening the scale.

HYMENOPTEROUS PARASITES OF THE NIGRA SCALE

Of the 24 or 25 species of hymenopterous parasites recorded from the nigra scale, 20 or 21 are primary parasites and 4 are secondary. The secondary parasites are *Eupelmus coccidivorus* Gahan, *Marietta* sp., *Quaylea whittieri* (Girault), and *Thysanus* sp.

The species of parasites (primary and secondary) of the nigra scale, and the recorded occurrence of each species, as to place and year reported, are as follows:

Aneristus ceroplastae Howard: Australia, 1931*; Hawaii, 1920, 1921, 1932; Puerto Rico, 1940*

Anysis saissetiae (Ashmead): Philippines, 1906

Coccophagus cowperi Girault: California, 1941*

* Unpublished records by S. E. Flanders, given in letters to the author.

Coccophagus hawaiiensis Timberlake: Hawaii, 1926
Coccophagus isipingoensis Compere: Transvaal, 1931
Coccophagus ochraceus Howard: California, 1941*
Coccophagus orientalis var. *modestus* Silvestri: Dahomey, French West Africa, 1915
Coccophagus pulvinariae Compere: California, 1941*
Coccophagus saissetiae Gahan: Panama, 1922
Coccophagus scutellaris (Dalman): Puerto Rico, 1940*
Diversinervus elegans Silvestri: Australia, 1931*
Encyrtus barbatus Timberlake: Hawaii, 1918, 1920
Encyrtus infelix (Embleton): Hawaii, 1920
Encyrtus sp.: Australia, 1931*
Eupelmus coccidivorus Gahan: Panama, 1925; Puerto Rico, 1940*
Lecaniobus cockerelli (Ashmead): Barbados, 1913; British Guiana, 1915, 1917; Puerto Rico, 1940*; St. Vincent, 1933; Trinidad, 1916; Virgin Islands, 1923
Marietta sp.: Puerto Rico, 1940
Metaphycus helvolus (Compere): California, 1939
Metaphycus stanleyi Compere: Kenya Colony, 1931
Microterys flavus (Howard): Hawaii, 1913
Microterys kotinskyi (Fullaway): Hawaii, 1920
Quaylea whittieri (Girault): California, 1937; Hawaii, 1913, 1918, 1932
Scutellista cyanea Motschulsky: California, 1936; Hawaii, 1906, 1913, 1918, 1920
Thysanus sp.: Puerto Rico, 1940*
Tomocera californica Howard: Hawaii, 1920

Seven of these were originally described from specimens reared from the nigra scale: *Coccophagus hawaiiensis* Timberlake, *C. isipingoensis* Compere, *C. orientalis* var. *modestus* Silvestri, *C. saissetiae* Gahan, *Encyrtus barbatus* Timberlake, *Eupelmus coccidivorus* Gahan, and *Anysis saissetiae* (Ashmead).

In the early papers by Nietner (1861, 1862, 1863), the statement is made that no parasites had been reared from the scale. The earliest record of hymenopterous parasites of the nigra scale is by Douglas (1891), who stated that specimens of the scale received from Georgetown, Demerara, British Guiana, May 28, 1889, "in nearly every instance had been attacked by parasites which had caused the legs and antennae to be at least partly malformed." In 1893 Cockerell reported that of 35 scales on the underside of a leaf sent to him from Antigua, 22 showed emergence holes of a parasite. He did not identify the parasite but described it briefly as "a chalcidid, with a large and thick tibial spur; femur and tibia brown; tarsus whitish, stigmal vein rather long, bifucate at end; postmarginal about as long as stigmal." This characterization, and the fact that the emergence holes were evidently in adult scales, indicate that the parasite may have been *Scutellista cyanea*. In 1905 Craw reared a parasite from the nigra scale on ferns in Hawaii, and this parasite was later described by Timberlake (1919*a*) as a new species, *Encyrtus barbatus*. During the period from 1905 to 1940, records of parasites were presented in twenty-nine published accounts of the nigra scale. A statement by Gowdey (1925), that *Arrhenophagus chionaspidis* Aurivillus had been reared from the nigra scale in Jamaica is probably erroneous, for the parasite named is believed not to attack lecanine scales.

Seven species of parasites have been reared from the nigra scale in California. These are *Coccophagus cowperi*, *C. ochraceus*, *C. pulvinariae*, *C. scutellaris*, *Metaphycus helvolus*, *Quaylea whittieri*, and *Scutellista cyanea*. *Meta-*

* Unpublished records by S. E. Flanders, given in letters to the author.

phycus helvolus and *S. cyanea* have been of considerable importance in the natural control of the nigra scale in California. In 1938 and 1939 an attempt was made to colonize *C. rusti* Compere, *Metaphycus stanleyi*, *Diversinervus smithii* Compere, and *Mesopeltis* sp. on the nigra scale. These species are parasites of the black scale and were introduced from Africa by Compere in 1936–37. No recovery of the parasites has been made from the nigra scale.

Aneristus ceroplastae.—The synonyms of *Aneristus ceroplastae* Howard include *Coccophagus ceroplastae* (Howard), *C. orientalis* Howard, and *Prococcophagus orientalis* (Howard). According to Compere (1936), this species is widely distributed in tropical and subtropical regions of the world, and has been recorded from 13 species of lecanine scales. It was first reported from the nigra scale by Fullaway (1920), who reared it from that scale in Hawaii and recorded it under the name *P. orientalis.* In 1921 it was brought on the nigra scale from Hawaii to California where, according to Smith and Compere (1928), an unsuccessful attempt was made to propagate it on the black scale. In 1933 it was again brought on the nigra scale from Hawaii, and was released on the soft (brown) scale at Colton, California. In June, 1934, it was recovered from that scale, collected at Colton. This appears to be the only evidence as to whether *A. ceroplastae* exists at present in California.[19] In 1931 Flanders reared *A. ceroplastae* from the nigra scale in Australia, and in 1940 he reared it from the nigra scale in material received from Puerto Rico.[20]

Anysis saissetiae.—*Anysis saissetiae* (Ashmead) was described by Ashmead (1906) under the name *Eurycranium saissetiae,* from 3 females and 7 males reared from the nigra scale in the Philippines by Tyler Townsend. According to Smith and Compere (1928), the parasite is fairly common in the Orient, where it attacks lecanine scales. It is not known to exist in California, but an attempt was made to establish it here many years ago.

Coccophagus cowperi.—*Coccophagus cowperi* Girault was described by Girault in 1917 from specimens reared from *Stictococcus gowdeyi* (Newstead) collected in Uganda, Africa. The identity of parasites designated *C. cowperi* and colonized in California is apparently a matter that warrants further study. Smith and Compere (1928) treated *cowperi* as a synonym of *C. lecanii* (Fitch) and stated that the species was colonized on the black scale in California with specimens received from Cape Town, South Africa. Concerning the identity of the species thus colonized, Smith and Compere (1928) quote from a letter from A. B. Gahan as follows: "Your *Coccophagus* sp. is certainly *C. cowperi* Girault, and I believe it not different from *C. lecanii* (Fitch)." Compere (1940*b*) overlooked the foregoing reference and stated that *C. cowperi* had not previously been colonized in California. At any rate, a species now known as *C. cowperi,* in California, was sent on the black scale from Cape Town, South Africa, by Compere in 1936–37. This parasite was liberated on the nigra scale in Balboa Park, San Diego, in the fall of 1937 and in Santa Monica in May, 1938. It became established in Balboa Park, as shown by rearings made by the writer in February, 1941, but it has not been recovered elsewhere in California from the nigra scale. It attacks the late second- and early third-instar stages, and causes the dorsum of the scale to turn

[19] Flanders, S. E., in letter to the author, April 28, 1942.

[20] Flanders, S. E., in letters to the author, September 22, 1939, and August 31, 1940.

black. Flanders (Compere, 1940*b*, p. 400) states that the male is a direct secondary ectoparasite.

Coccophagus hawaiiensis.—According to Timberlake (1926), *Coccophagus hawaiiensis* Timberlake was given the name *hawaiiensis* by L. O. Howard, without a description, in 1894 and had been mentioned the preceding year by W. G. Wait, both records pertaining to specimens taken from *Pulvinaria camellicola* Sign. and *Lecanium* sp. in Hawaii. *C. hawaiiensis* was finally described by Timberlake (1926) from specimens reared from the nigra scale at Honolulu. The parasite does not occur in California.

Coccophagus isipingoensis.—*Coccophagus isipingoensis* Compere was described by Compere (1931) from specimens from South Africa, reared in 1925–26 from the soft (brown) scale, the black scale, *Saissetia persimile* (News.), and *Filippia carissae* Brain. It does not occur in California.

Coccophagus ochraceus.—The only record of *Coccophagus ochraceus* Howard on the nigra scale is a single specimen reared by the author from a half-grown nigra scale taken at San Diego, California, in March, 1941. According to Smith and Compere (1928), the species is known to have been in California since 1887, when it was reared from a *Lecanium* sp. at Alameda, and was described as a new species, from the Alameda specimens, by L. O. Howard in 1895. As a parasite of the black scale, it is prevalent in South Africa (Compere, 1940*b*), and at times rather prevalent in California.

Coccophagus orientalis var. *modestus.*—Silvestri (1914) described *Coccophagus orientalis* var. *modestus* Silvestri from specimens reared from the nigra scale taken in Dahomey, French West Africa. Smith and Compere (1926) considered this to be the same species that had been reared from the black scale at Cape Town, South Africa, as early as 1900, and that had been repeatedly introduced into California during the period 1912 to 1921. Subsequently, however, Compere (1931, 1940*b*) decided that the South African parasite was a new species and named it *C. capensis*. *C. orientalis* var. *modestus* is known, therefore, only from the original record by Silvestri in 1914.

Coccophagus pulvinariae.—*Coccophagus pulvinariae* Compere was propagated in California from specimens sent by Compere on the black scale from Pretoria and Johannesburg, South Africa, in 1937. It was released on the nigra scale at Santa Paula, California, and was recovered from that host in the same locality in 1940.[21] It was also colonized on the black scale in southern California in 1937 (Compere, 1940*b*), but apparently it did not become permanently established on that host.

Coccophagus saissetiae.—Gahan (1922) described *Coccophagus saissetiae* Gahan from 3 female and 3 male specimens reared from the nigra scale in the Canal Zone. There appear to be no other records of the parasite from that host. It does not occur in California.

Coccophagus scutellaris.—*Coccophagus scutellaris* (Dalman) was described by Dalman in 1825, and in 1894 Howard erroneously described it as a new species under the name *C. lunulatus*, from a specimen collected in California (Smith and Compere, 1928). The species, known best by the latter name until 1931 (Compere, 1931), has long been a fairly common parasite of the soft (brown) scale, the hemispherical scale, the black scale, and the brown apricot

[21] Flanders, S. E., in letter to the author, August 19, 1940.

scale in California. The writer has often found it to be prevalent on these scales where the nigra scale was abundant, but he has reared it from the nigra scale only in the southern region of San Francisco Bay. It was reared by Flanders from the nigra scale received from Puerto Rico in May, 1940.[22]

Diversinervus elegans.—*Diversinervus elegans* Silvestri is a prevalent parasite of the black scale in Africa. Flanders reared it from the nigra scale in Australia in 1931.[23] It has not been established in California.

Encyrtus barbatus.—Timberlake (1919*b*) described *Encyrtus barbatus* Timberlake from specimens reared in Hawaii from the hemispherical scale in 1905 and 1917, and from the nigra scale in 1917 and 1919. It is widely distributed in tropical and subtropical regions, including California, but has never been reared from the nigra scale here.

Encyrtus infelix.—Fullaway (1920) records *Encyrtus infelix* (Embleton) from the nigra and the hemispherical scales in Hawaii. It is said to be widely distributed over the world. In California it is well known as a parasite of the hemispherical scale, but has not been reared from the nigra scale.

Eupelmus coccidivorus.—Gahan (1924) described *Eupelmus coccidivorus* Gahan from specimens reared from *Ceroplastes* sp. at Las Sabanas, Panama, in 1921 and from the nigra scale at Ancon, Canal Zone. In May, 1940, Flanders reared *Eupelmus coccidivorus* from the nigra scale received from Puerto Rico.[24] The species does not occur in California.

Lecaniobus cockerelli.—*Lecaniobus cockerelli* (Ashmead) has been repeatedly recorded from the nigra scale in the West Indies and British Guiana. It was described by Ashmead in 1896 from specimens reared from *Lecanium fraternum* Cockerell at Antigua. Crawford (1908) redescribed it as *Zalophothrix mirum* from specimens reared from the nigra scale at Barbados, and in 1911 he discovered that *Z. mirum* is a synonym of *Lecaniobus cockerelli.* In 1915 an unsuccessful attempt was made to establish this parasite on the black scale in California (Smith and Compere, 1928). The parasite is not known to exist in California at present.

Marietta sp.—Flanders[25] reared an undetermined species of *Marietta* from a shipment of the nigra scale from Puerto Rico in May, 1940. The species is presumably a secondary parasite.

Metaphycus helvolus.—Compere (1926) described *Metaphycus helvolus* (Compere) from specimens reared from the black scale from South Africa. In 1936–37 it was brought to California and propagated on the black scale in the insectary. In 1937 it was colonized outdoors on that scale and on the nigra scale, and it has become well established on these hosts. According to Flanders (1940), it also attacks the hemispherical scale, the brown apricot scale, and the citricola scale, *Coccus pseudomagnoliarum* (Kuw.). Various facts regarding the biology of the parasite and its colonization on the black scale in California are given by Flanders (1940).

The only record of *Metaphycus helvolus* on the nigra scale is in California. The first liberation of the parasite on this scale was made in the West Los Angeles area on May 18, 1938. On that date 400 parasites were released on

[22] Flanders, S. E., in letter to the author, August 31, 1940.
[23] Flanders, S. E., in letter to the author, September 22, 1939.
[24] Flanders, S. E., in letter to the author, August 31, 1940.
[25] Flanders, S. E., in letter to the author, August 31, 1940.

shrubs that were infested very heavily by the nigra scale. The first recovery of the parasite was made in July, 1939. On September 20, 1939, 2,000 more were released in the same location. During the fall and winter the parasite became prevalent, and it remained so through 1940 and 1941. The question has arisen as to whether or not *M. helvolus* was responsible for the almost complete dying-out of the nigra scale throughout most of the infested area from Santa Barbara to San Diego during the summer and fall of 1939 and the early part of 1940. This question is discussed under "Rise of Natural Enemies to Dominance over the Nigra Scale in Southern California" (p. 283).

Metaphycus stanleyi.—*Metaphycus stanleyi* Compere was collected by Compere (1940*b*) on the black scale at Cape Town, South Africa, in March, 1937, and was propagated at Riverside, California, from material sent by Compere. In his description of the species, Compere (1940*a*) states that what appears to be the same species is represented by 8 females reared from the nigra scale collected at Kiambu, Kenya Colony, in 1931. Flanders[20] states that the parasite is widely distributed in southern California and occasionally cleans up infestations of soft (brown) scale, and black scale. The writer has reared it from the soft (brown) and the tessellated scales at Santa Barbara, but has not reared it from the nigra scale.

Microterys flavus.—The only record of *Microterys flavus* (Howard) taken from the nigra scale is by Fullaway (1913) in Hawaii. The parasite was described by Howard from specimens reared from the soft (brown) scale in Los Angeles in 1880. It is a common parasite of several species of lecanine scales in California, but has not been reared from the nigra scale here.

Microterys kotinskyi.—*Microterys kotinskyi* (Fullaway) is recorded by Fullaway (1920) in Hawaii from the nigra scale and from several other species of lecanine scales. It does not exist in California.

Quaylea whittieri.—There are four published records of the rearing of the secondary parasite *Quaylea whittieri* (Girault) from the nigra scale. All the records are from Hawaii. Fullaway (1913) recorded it under the name *Hemencyrtis* sp.; Timberlake (1919*b*) recorded it from the nigra scale under the name *Q. aliena* Timberlake; Fullaway (1920) recorded it as a hyperparasite on the nigra scale through *Microterys kotinskyi* and *S. cyanea;* and Fullaway (1932) again recorded it as a hyperparasite of the nigra scale. The writer has reared it in California from the nigra scale taken at Centerville, Palo Alto, Los Gatos, and Los Angeles, in the years 1937, 1938, and 1939. In these instances it was presumed to be a primary parasite of *S. cyanea.* It has been relatively scarce, however, even where parasitism of the scale by *S. cyanea* has been high.

Scutellista cyanea.—The only published records of *Scutellista cyanea* Motschulsky from the nigra scale are from Hawaii. During the period 1936–1941, it was observed to be a prevalent parasite of that scale in California. It was introduced into Hawaii in 1905, and on October 15, 1905, the announcement was made that the species had been successfully reared on the nigra scale (Anon., 1906). Subsequently, mention of the parasite from that host was made by Fullaway (1913, 1920) and Timberlake (1919*b*). In California, *S. cyanea* is better adapted to the nigra scale than to any other scale; for the parasite

[20] Flanders, S. E., in letter to the author, October 27, 1941.

larvae feeds upon the eggs of the host, and the egg-laying period of this scale commonly extends over a period of months, much longer than that of other lecanine scales. In other words, several generations of the parasite may develop on one generation of this scale, while but one generation normally develops on a given generation of any other species of scale.

The percentage of scales parasitized has been found to vary greatly within any locality. The parasite is a weak flier and explores quite thoroughly any plant on which it may emerge. On the campus of the University of California, in September, 1938, the percentage of scales attacked by *Scutellista cyanea* ranged from 0.6 to 21.3 on shrubs located in different parts of the campus. The percentages of scales found to have been attacked in various localities in the coastal region, as shown by studies made in September, 1939, are as follows: Whittier, 8; Pasadena, 12.4; Santa Monica, 8.5; Santa Barbara, 34; Santa Maria, 50; San Luis Obispo, 0.2; Salinas, 3.7; Watsonville, 0.8; Los Gatos, 80; Palo Alto, 20; Redwood City, 4.4

Thysanus sp.—Flanders reared four specimens of an undetermined species of *Thysanus* from the nigra scale shipped to him from Puerto Rico in May, 1940.[27] The species is regarded as a hyperparasite.

Tomocera californica.—The only published record of *Tomocera californica* Howard from the nigra scale is by Fullaway (1920), in Hawaii. The species was described in 1880 from specimens reared from the black scale at Los Angeles, California; and at one time it was a prevalent parasite of the latter in California (Smith and Compere, 1928). For many years it has been scarce. So far as is known, it has never been reared from the nigra scale in California. The larva of the parasite feeds upon the eggs of the host scale.

FUNGUS PARASITES OF THE NIGRA SCALE

Seven species of fungi have been reported to attack the nigra scale in various tropical and semitropical parts of the world. *Aschersonia* sp. and *Bactocera rubus* were reported (Anon., 1921) to have checked infestations of nigra scale on rubber trees in Ceylon. Dupont (1925) stated that in Seychelles the nigra scale was attacked by species of *Fusarium, Cephalosporum,* and *Hypocrella. Hypocrella* was also reported from the nigra scale in Seychelles in 1913. Wolcott (1933) reported that in the West Indies the scale is attacked by *Cephalosporum lecanii.* Petch (1926) described *Corenium pulcherrimum* as a new species, obtained from the nigra scale. In Hawaii, the nigra scale was reported to be badly attacked by a fungus, probably *Entomophthora pseudococci* (Anon., 1929; Illingsworth, 1929). In the reports cited above, no particulars are given concerning the biology of the various fungi or the stages of the scale attacked.

In correspondence and in conversation with entomologists from Hawaii and the West Indies, the writer has been told that, under the conditions of high humidity and high moisture during certain months in those regions, all the scales on the leaves and bark of particular infested branches are sometimes attacked by fungi. Fungus parasites have not been observed or reported in California, although a symbiotic fungus occurs within the bodies of the scale (p. 273).

[27] Flanders, S. E., in letter to the author, August 31, 1940.

RISE OF NATURAL ENEMIES TO DOMINANCE OVER THE NIGRA SCALE IN SOUTHERN CALIFORNIA

During the years 1936, 1937, and 1938, natural enemies appeared to be of little importance in the control of the nigra scale in California. In 1939 they became exceedingly effective in the southern coastal districts, but in the northern districts the pest maintained its population relatively unchanged. In the southern districts the hymenopterous parasite *Scutellista cyanea* and numerous species of predaceous insects and mites were observed in small numbers on infested plants during the years 1937 and 1938, but in no locality observed did the scale population decline. In the early summer of 1939, it was not uncommon to find from 25 to 100 adult scales and from 1,000 to 2,000 young scales on one leaf of *Pittosporum undulatum*. By the middle of July 1939, it had become evident that natural enemies were far more numerous and effective than they had been in preceding years. By the middle of August the destruction by enemies had attained such proportions that in some locations one had to search carefully to find a live young scale. The surface of leaves appeared to be covered by chaff made up of the dead bodies of young scales turned on edge and crumpled by predators that had sucked out the contents of the bodies (fig. 21).

The adult scales suffered considerably from the activity of *Scutellista cyanea*, *Rhizobius ventralis*, and *Lindorus lophanthae*, but the highest toll by these three insects, as shown by examinations made in October, 1939, was 19 per cent. While egg laying and hatching continued in diminishing proportions until all adult scales had died, in midwinter, predators and parasites maintained their supremacy. The young scales were attacked soon after they became established, and approached extermination even in locations that had escaped the full force of natural enemies in preceding months. The hymenopterous parasite *Metaphycus helvolus* became increasingly effective in the winter, and thereafter became an important natural enemy of the scale. In the southern coastal districts during 1940, no widespread infestation of the scale occurred. In the northern region, from San Luis Obispo to Santa Rosa, where the infestations had never been so heavy or so widespread, the condition in 1940 was about the same as in preceding years.

SPRAYING FOR THE CONTROL OF THE NIGRA SCALE

The results of numerous experiments, together with the practical experience of nurserymen, commercial spray operators, and municipal park and street departments, have shown that the nigra scale is more difficult to control than are other species of lecanine scales commonly infesting ornamental shrubs and trees. The reasons are that adult, egg-laying scales exist for a period of many months, from the first of June until about the first of the succeeding February, and that sprays have but little effect on the adults. With the black, the hemispherical, and the brown apricot scales, egg laying is completed within a period of 6 weeks or 2 months. The soft (brown) and the elongate scales may occur in the adult stage at different months during the year, but the adults can be killed by spray because their bodies are soft. The tessellated scale exists in the adult stage and reproduces over a period of several months, but because

the body of the adult is very thin and fairly soft, this scale also can be controlled by spraying.

Oil Spray Recommended.—In the course of these investigations, tests were made with various grades of spray oils and with numerous spray products available to home gardeners for the control of scale insects. The spray products included preparations containing pyrethrum, rotenone, nicotine, and oils in various forms. The results of the tests and the results of commercial spray treatments show very definitely that highly refined oil sprays, often called foliage or summer oil sprays, are superior to other insecticides in the control of the nigra scale. The light-medium oil is preferred. The oils are available in the form of paste emulsions, flowable emulsions, and emulsive oils. The first two types are somewhat preferred because they are more easily dispersed in the water in the spray tank. Paste emulsions contain about 83 per cent oil, flowable emulsions from 80 to 90 per cent, and emulsive oils 98 or 99 per cent. Paste emulsions and flowable emulsions may be used at the rate of 2 gallons and emulsive oils at the rate of 1½ to 1⅔ gallons to 100 gallons of water.

The light-medium grade of highly refined oil spray is the most practical grade for general use in the control of scale insects of all kinds, and also in the control of mites, on ornamental shrubs and trees. Medium and heavy grades of oil are more effective in killing adult scales, but they also cause more leaf drop.

Thorough Application Important.—In spraying for the nigra scale, it should be borne in mind that the scales infest the smooth bark and the upper and lower sides of the leaves. In heavy infestations several hundred insects may occur on each side of every leaf. Even in light infestations, some parts of a shrub or tree may bear several hundred scales to the leaf. Drenching quantities of spray must be applied if a coating of oil is to be effected on all infested parts. The lower sides of the leaves are particularly difficult to cover with spray. When small hand sprayers, bucket sprayers, and knapsack sprayers are used, the branches should be lifted with one hand so that the spray can be directed against the lower side of the leaves. Where spraying is done with a power sprayer, the spray nozzle can be oscillated so that the force of the spray will turn the leaves.

Theoretically, spraying should be done in midwinter after egg laying has been completed and all the eggs have hatched. There are two reasons, however, why spraying in midwinter may not be entirely satisfactory: (1) in some years, and in certain locations every year, many scales will become too large by midwinter to be readily killed with oil spray at the recommended strength; (2) winter applications of oil spray sometimes cause marked defoliation and, in the case of weak plants, they may cause the death of branches. October is probably the best month for spraying. Good results may be obtained, however, by spraying in September, October, and November, the degree of control varying with the extent that hatching has been completed in any particular location. Under such a condition of infestation as that shown in figure 17, with large numbers of adult egg-laying scales present, spraying in September would result in poor control.

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